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THE

MINERALOGICAL MAGAZINE

AND

Journal of The Mineralogical Society.

INSTITUTED FEBRUARY 3, 1876.

EDITED BY L. J. SPENCER, M.A.

ASSISTED BY A COMMITTEE OF COUNCIL.

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1914.

MINERALOGICAL SOCIETY.

(*Instituted February* 3, 1876.)

BYE-LAWS.*

1. The object of the Mineralogical Society of Great Britain and Ireland, with which the Crystallological Society was amalgamated on December 11, 1883, shall be to advance the knowledge of Mineralogy, and also of Crystallography and Petrology.

2. The Society shall consist of Ordinary Members and Honorary Members.

Ordinary Members.

3. Every candidate for Ordinary Membership shall be proposed by two Ordinary Members, one, at least, of whom shall have personal knowledge of the candidate.

4. Elections to Ordinary Membership shall be made by the Council, and shall be confirmed at the ensuing general meeting by a majority consisting of three-fourths of the Members present and voting.

5. Ordinary Members shall pay an entrance fee of one guinea and an annual subscription of one guinea. Ordinary Members elected on or before November 13, 1900, shall be entitled to compound for the annual subscription by a single payment of ten guineas: Ordinary Members elected after that date shall be entitled to compound for the annual subscription by a single payment of fifteen guineas.

6. Annual Subscriptions shall be due on the first of January of each year, but Members elected after the first of October shall not be required to pay a subscription for the then current year.

7. The name of any Ordinary Member whose subscription is more than two years in arrear shall be brought before the Council, and an intimation that this action has been taken shall be communicated to the Member. After the expiration of at least one year from that date, the Council shall be empowered to erase the name from the List of Members.

* Adopted at the Anniversary Meetings of November 13, 1900, and November 18, 1902.

Honorary Members.

8. Twenty persons, non-resident in the United Kingdom, may be elected Honorary Members. They shall pay neither entrance fee nor annual subscription.

9. Every candidate for Honorary Membership shall be proposed by two Members of the Council, and the election shall be by the Council, and shall be confirmed at the ensuing general meeting by a majority consisting of three-fourths of the Members present and voting.

Council.

10. The Society shall be governed by a Council, consisting of a President, two Vice-Presidents, a General Secretary, a Foreign Secretary, a Treasurer, an Editor of the Journal, and twelve Ordinary Members.

11. All members of the Society who have served the office of President shall be life-members of the Council.

12. The Council shall be elected annually at the Anniversary Meeting.

13. Four Ordinary Members of Council shall retire annually, and shall not be eligible for re-election until the next Anniversary Meeting.

14. The Council shall prepare a List of Members nominated for election as Officers and Ordinary Members of Council.

15. The election of Council shall be effected by the agency of voting papers containing the List nominated by the Council. They shall be sent by the General Secretary, at least four weeks before the Anniversary Meeting, to every Ordinary Member of the Society, and every such Member shall be entitled to substitute the names of any other Ordinary Members of the Society for those on the List.

16. The voting papers shall be returned by the Members to the General Secretary, and shall be examined at the Anniversary Meeting by two Scrutineers appointed by the Chairman, who shall on their report declare the result of the election. The voting papers need not be signed.

17. The Council shall have power to appoint Officers, and to co-opt Ordinary Members of Council, to fill vacancies in the Council caused by death or resignation during the interval between two Anniversary Meetings.

18. Meetings of the Council shall be summoned by order of the President or the Council; at such meetings three shall be a quorum, of whom

one shall be either the President, a Vice-President, the Treasurer, or the General Secretary.

19. A Report of Council on the work and progress of the Society shall be submitted to each Anniversary Meeting.

Trustees.

20. Two or more Trustees shall be appointed by the Council, and the invested property of the Society shall stand in their names.

21. Composition-fees shall be treated as Capital: a Resolution of the Society at a general meeting, summoned with notice of a proposed disposition of property, shall be sufficient authority to the Trustees to give effect to such disposition; provided that a resolution of the Council shall be sufficient authority for any change of investment.

Meetings.

22. Meetings of the Society shall be summoned from time to time, as may be deemed necessary by the Council, or at the requisition of any ten Members of the Society. One of these meetings in each year shall be termed the Anniversary Meeting.

Journal.

23. The Numbers of the *Mineralogical Magazine and Journal of the Society* shall be issued at such intervals as the Council shall determine, and shall be sent, postage paid, to every Member of the Society.

Auditors and Balance Sheet.

24. Two Ordinary Members of the Society, one of whom is not a Member of the Council, shall be appointed annually by the Council to audit the accounts of the Society.

25. No auditor shall serve for more than three years in succession.

26. The audited Balance Sheet, after submission to the Council, shall be published in the Journal of the Society as early as possible in every year.

Expulsion of Members.

27. A majority consisting of three-fourths of the whole Council shall have power to expel a Member from the Society, but a Member who has been expelled shall have a right of appeal to the Society. Notice of such appeal to the Society shall be sent by such Member to the

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8. Twenty persons, non-resident in the United Kingdom, may be elected Honorary Members. They shall pay neither entrance fee nor annual subscription.

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General Secretary within four weeks of the expulsion, and the appeal shall be considered by the Society at the next Anniversary Meeting; a majority of the votes recorded at such Meeting sufficing to confirm or annul the decision of the Council.

Alteration of the Bye-Laws.

28. The Bye-laws may be altered only at an Anniversary Meeting, and only by a majority consisting of three-fourths of the Members present and voting. Notice of changes proposed to be made in the Bye-laws shall be communicated by the General Secretary to every Ordinary Member of the Society at least four weeks before the Anniversary Meeting at which they are to be considered.

Obligation Book.

29. Ordinary Members, by payment of their entrance fee, signify their acceptance of any Bye-laws approved by the Society; and every Member of the Society shall sign an Obligation Book.

LIST OF MEMBERS.

(*November*, 1913.)

HONORARY MEMBERS.

Year of Election.

1905 Baumhauer, Heinrich. Professor of Mineralogy in the University of *Freiburg, Switzerland.*

1909 Becke, Friedrich Johann. Professor of Mineralogy and Petrography in the University of *Vienna.*

1895 Brögger, Waldemar Christofer. Professor of Mineralogy and Geology, and Rector of the University, *Christiania.*

1909 Cesàro, Giuseppe. Professor of Mineralogy in the University of *Liége.*

1913 Clarke, Frank Wigglesworth. Chief Chemist, *United States Geological Survey, Washington, D.C., U.S.A.*

1897 Dana, Edward Salisbury. Yale University, *New Haven, Conn., U.S.A.*

1910 Fedorov, Evgraf Stepanovič. Professor of Mineralogy in the Institute of Mines (Gornyi Institut) of the Empress Catherine II, *Vassili Ostrov, St. Petersburg.*

1912 Goldschmidt, Victor. Professor of Mineralogy in the University of Heidelberg. 9 *Gaisbergstrasse, Heidelberg.*

1877 Groth, Paul Heinrich von. Professor of Mineralogy in the University of Munich. *Brieffach, München VI.*

1900 Lacroix, Alfred. Professor of Mineralogy in the Muséum National d'Histoire Naturelle. 61 *Rue de Buffon, Paris.*

C[1] Lang, Victor von. Professor of Physics in the University of Vienna. *Physikalisches Institut der Universität, Vienna.*

1903 Liebisch, Theodor. Professor of Mineralogy in the University of Berlin. *Mineralogisch-petrographisches Institut, Invalidenstrasse* 43, *Berlin No.* 4.

1883 Ludwig, Ernst. 9 *Allgemeines Krankenhaus, Vienna.*

1879 Rosenbusch, Harry. Formerly Professor of Mineralogy and Geology in the University of *Heidelberg.*

[1] C = Corresponding Member of the Crystallological Society at the time of the amalgamation of the two societies, December 11, 1883.

Year of Election.

1903 Strüver, Giovanni. Professor of Mineralogy in the Royal University of *Rome.*

1879 Tschermak, Gustav. The University, *Vienna.*

1912 Viola, Carlo Maria. Professor of Mineralogy in the University of *Parma, Italy.*

1913 Wallerant, Frédéric. Professor of Mineralogy in the University, *Laboratoires à la Sorbonne, Paris.*

ORDINARY MEMBERS.[1]

A Annual Subscribers.
L Life-Members.
C Belonged to the Crystallological Society at the time of the amalgamation of the two Societies, December 11, 1883.

Year of Election.

A 1881 Baker, Harry, F.I.C., F.C.S. *Epworth House, Maughland Lane, Runcorn, Cheshire.*

A 1904 Barker, Thomas Vipond, M.A., B.Sc. (Oxon.), F.C.S. *Department of Mineralogy, University Museum, Oxford.*

L 1894 Barlow, William, F.R.S. *The Red House, Stanmore, Middlesex.*

L 1876 Barnett, Andrew Ketchan, F.G.S. 11 *Penrose Terrace, Penzance, Cornwall.*

A 1913 Barreto, Dr. Antonio de Barros. Professor of Mineralogy and Geology in the Polytechnic School of São Paulo. *Rua Maranhão* 60, *Hygienopolis, São Paulo, Brazil.*

L 1893 Barrow, George, F.G.S. Geological Survey of England, *The Museum,* 28 *Jermyn Street, London, S.W.*

L 1897 Beale, Sir William Phipson, Bart., K.C., M.P., F.G.S., F.C.S. 6 *Stone Buildings, Lincoln's Inn, London, W.C.*

L 1912 Bell, Robert. 64 *Newington Avenue, Belfast.*

L 1888 Bemrose, Henry Howe, J.P., M.A., Sc.D., F.G.S. *Ash Tree House, Osmaston Road, Derby.*

A 1894 Beringer, John Jacob, A.R.S.M., F.I.C., F.C.S. *School of Metalliferous Mining, Camborne, Cornwall.*

A 1906 Blake, George Stanfield, B.Sc., A.R.S.M., F.C.S. *Standard Oil Company of Canada, Tilbury, Ontario.*

[1] Corrections for this List should be sent to the General Secretary.

	Year of Election.	
L	1876	Bonney, Rev. Thomas George, Sc.D., LL.D., F.R.S. Emeritus Professor of Geology in University College, London. 9 *Scroope Terrace, Cambridge.*
A	1909	Bowen, David, F.G.S. *The University, Leeds.*
L	1897	Bowman, Herbert Lister, M.A., D.Sc., F.G.S., F.C.S. Professor of Mineralogy in the University of Oxford. *Department of Mineralogy, University Museum, Oxford.*
L	1876	Brown, Alexander Crum, M.A., M.D., D.Sc., F.R.S. Formerly Professor of Chemistry in the University of Edinburgh. 8 *Belgrave Terrace, Edinburgh.*
A	1912	Burkitt, Miles Crawford, B.A. *Trinity College, Cambridge.*
A	1901	Burls, Herbert Thomas, F.G.S. 16 *Victoria Street, London, S.W.*
L	1885	Butler, Francis Henry, M.A., A.R.S.M., L.S.A. (Lond.), 158 *Brompton Road, London, S.W.*
A	1903	Campbell, Donald Fraser, B.A., A.R.S.M., F.G.S. *Old Hunstanton, Norfolk.*
A	1876	Church, Sir Arthur Herbert, K.C.V.O., M.A., D.Sc., F.R.S. Formerly Professor of Chemistry in the Royal Academy of Arts. *Shelsley, Ennerdale Road, Kew, Surrey.*
A	1888	Cole, Grenville Arthur James, M.R.I.A., F.G.S. Director of the Geological Survey of Ireland, Professor of Geology in the *Royal College of Science for Ireland, Dublin.*
A	1913	Collingridge, Harvey, B.Sc., F.G.S., A.M.I.C.E. *Auburn, Denville, Havant, Hampshire.*
L	1892	Collins, Henry Francis, A.R.S.M. *Huelva Copper and Sulphur Mines, Ltd., Val de la Musa, Prov. de Huelva, Spain.*
L	1876	Collins, Joseph Henry, F.G.S. *Crinnis, Par Station, Cornwall.*
L	1900	Coomaraswamy, Ananda K., D.Sc., F.L.S., F.G.S., M.R.A.S. 39 *Brookfield, West Hill, Highgate, London, N.*
A	1907	Crook, Thomas, A.R.C.Sc.I., F.G.S. *Scientific and Technical Department, Imperial Institute, London, S.W.*
L	1888	Crookes, Sir William, O.M., D.Sc., LL.D., President R.S. 7 *Kensington Park Gardens, London, W.*
A	1899	Cullis, Charles Gilbert, D.Sc., F.G.S. Assistant-Professor of Geology in the *Imperial College of Science and Technology, South Kensington, London, S.W.*

	Year of Election.	
L	1899	Currie, James, M.A., F.R.S.E. *Larkfield, Golden Acre, Edinburgh.*
L	1876	Danby, Thomas William, M.A., F.G.S. *The Crouch, Seaford, Sussex.*
L	1885	Daw, John W. *Walreddon Manor, Tavistock, Devon.*
L	1898	De Castro, John Paul, M.A., F.C.S., F.I.C. 1 *Essex Court, Temple, London, E.C.*
A	1909	Dewey, Henry, F.G.S. Geological Survey of England. *The Museum, 28 Jermyn Street, London, S.W.*
L	1910	Drugman, Julien L. E., Ph.D. (Bonn), M.Sc., F.C.S. 5 *Moreton Road, Oxford.*
L	1891	Evans, John William, LL.B., D.Sc., F.G.S. Imperial Institute, London, S.W. 75 *Craven Park Road, Willesden Junction, London, N.W.*
L	1900	Fleischmann, Friedrich Noel Ashcroft, M.A., F.C.S., F.G.S. 37 *Palace Court, Bayswater, London, W.*
L	C	Fletcher, Lazarus, M.A., Hon. Ph.D. (Berlin), F.R.S. Director of the British Museum (Natural History), Cromwell Road, London, S.W. 35 *Woodville Gardens, Ealing, London, W.*
L	1895	Fletcher, Rev. Mark, M.A., F.G.S. Lecturer in Mineralogy in the Armstrong College, Newcastle-on-Tyne. *The Vicarage, Long Benton, Newcastle-on-Tyne.*
L	1902	Flett, John Smith, M.A., D.Sc., F.R.S. Assistant Director, Geological Survey of Scotland. 33 *George Square, Edinburgh.*
A	1912	Gardiner, Clarence Roe. *Care of Messrs. Tiffany & Co., 401 Fifth Avenue, New York, U.S.A.*
A	1876	Geikie, Sir Archibald, K.C.B., D.Sc., D.C.L., LL.D., Past-President R.S. Formerly Director-General of the Geological Survey of the United Kingdom. *Shepherd's Down, Haslemere, Surrey.*
A	1876	Geikie, James, LL.D., D.C.L., F.R.S. Professor of Geology and Mineralogy in the University of Edinburgh. *Kilmorie, Colinton Road, Edinburgh.*
L	1881	Gibb, T. J.
L	1902	Giles, William B., F.I.C. *The Grange, Leyton, Essex.*
L	1886	Goldschmidt, Victor, Ph.D., Professor of Mineralogy in the University of Heidelberg. 9 *Gaisbergstrasse, Heidelberg, Germany.*

Year of Election.

A 1905 Goodchild, Wilbert, M.B., Ch.B. (Edin.). *Blencathra Sanatorium, Threlkeld, Penrith, Cumberland.*

A 1895 Gordon, Rev. John More, M.A., F.G.S. 7 *Moreton Gardens, South Kensington, London, S.W.*

A 1903 Grabham, George Walter, M.A., F.G.S. Geologist to the Sudan Government. *Box* 178, *Khartoum, Sudan.*

A 1913 Graham, Richard Percival Devereux, B.A. (Oxon). Assistant Professor of Mineralogy, *McGill University, Montreal, Canada.*

L 1892 Gregory, John Walter, D.Sc., F.R.S. Professor of Geology in the *University of Glasgow.*

A 1911 Hall, Thomas Clifford Fitzwilliam, F.G.S., Assoc. Inst. M.M. Lecturer in Geology and Mineralogy, *School of Metalliferous Mining, Camborne, Cornwall.*

A 1912 Hallimond, Arthur Francis, B.A., F.G.S. Assistant Curator, *Museum of Practical Geology*, 28 *Jermyn Street, London, S.W.*

A 1908 Harger, Harold Scott, F.G.S. *P. O. Box* 1945, *Johannesburg, Transvaal.*

A 1885 Harker, Alfred, M.A., F.R.S. Fellow of St. John's College, Cambridge. *St. John's College, Cambridge.*

L 1900 Hartley, Harold Brewer, M.A., F.C.S. *Balliol College, Oxford.*

A 1910 Hatch, Frederick Henry, Ph.D., M.Inst.C.E., F.G.S. 15 *Copse Hill, Wimbledon, Surrey.*

A 1910 Henson, Mrs. F., 97 *Regent Street, London, W.*

A 1879 Henson, Samuel, 97 *Regent Street, London, W.*

A 1910 Heslop, Miss Mary Kingdon, M.Sc. Demonstrator in Mineralogy in the Armstrong College, Newcastle-on-Tyne. 20 *Framlington Place, Newcastle-on-Tyne.*

L 1907 Hilton, Harold, M.A., D.Sc. Professor of Mathematics in the University of London. 108 *Alexandra Road, South Hampstead, London, N.W.*

A 1888 Hoffmann, G. Christian, LL.D. *Care of A. F. May, Esq., Carleton Chambers*, 74 *Sparks Street, Ottawa, Canada.*

L 1896 Holland, Sir Thomas Henry, K.C.I.E., A.R.C.S., D.Sc., F.R.S. Formerly Director of the Geological Survey of India. Professor of Geology and Mineralogy in the Victoria

	Year of Election.	
		University of Manchester. *Westwood, Alderley Edge, Manchester.*
A	1908	Hopkins, Edward. 58B *Hatton Garden, London, E.C.*
A	1902	Howe, John Allen, B.Sc., F.G.S. Curator of the Museum of Practical Geology. *The Museum,* 28 *Jermyn Street, London, S.W.*
A	1878	Hughes, Thomas McKenny, M.A., F.R.S. Professor of Geology in the University of Cambridge. *Ravensworth, Brooklands Avenue, Cambridge.*
L	1890	Hutchinson, Arthur, M.A., Ph.D., F.C.S., F.G.S. Demonstrator of Mineralogy in the University of Cambridge. *Pembroke College, Cambridge.*
A	1899	Jackson, Henry, M.A., B.Sc., F.C.S. 3 *Lygon Road, Edinburgh.*
A	1905	Jones, Bernard Mouat, M.A., F.C.S. Assistant Professor of Chemistry, Imperial College of Science and Technology. 15 *Harrington Gardens, South Kensington, London, S.W.*
A	1908	Jones, Owen Thomas, M.A., D.Sc., F.G.S. Professor of Geology in the University College of Wales. *University College, Aberystwith.*
L	1884	Judd, John Wesley, C.B., LL.D., F.R.S. Formerly Professor of Geology in, and Dean of, the Royal College of Science, South Kensington, S.W. *Orford Lodge,* 30 *Cumberland Road, Kew, Surrey.*
L	1876	Kinch, Edward, F.C.S., F.I.C. Professor of Chemistry in the *Royal Agricultural College, Cirencester.*
L	1876	Kitto, Benedict, F.I.C., F.G.S. 26 *Lancaster Road, Finsbury Park, London, N.*
A	1909	Knowles, Thomas, B.A., B.Sc. *School of Metalliferous Mining, Camborne, Cornwall.*
A	1913	Kotō, Bundjirō, Ph.D. Professor of Geology in the *College of Science, Imperial University, Tokyo, Japan.*
A	1907	Krantz, Friedrich Ludwig Robert, Ph.D. 36 *Herwarthstrasse, Bonn, Rhenish Prussia.*
A	1885	Kunz, George Frederick, M.A., Ph.D., Sc.D., F.G.S. 401 *Fifth Avenue, New York City, U.S.A.*
A	C	Lewis, William James, M.A., F.R.S., Professor of Mineralogy in the University of Cambridge. *The New Museums, Cambridge.*

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A	1886	Lindsey, C. R., B.Sc. 3 *Demesne Road, Whalley Range, Manchester.*
L	C	Liveing, George Downing, M.A., Hon. Sc.D., F.R.S. Formerly Professor of Chemistry in the University of Cambridge. *Newnham, Cambridge.*
L	1876	Liversidge, Archibald, M.A., Hon. LL.D., F.R.S. Formerly Professor of Chemistry in the University of Sydney, New South Wales. *Fieldhead, George Road, Coombe Warren, Kingston, Surrey.*
A	1879	Louis, Henry, M.A., D.Sc., A.R.S.M., F.G.S. Professor of Mining in the *Armstrong College, Newcastle-on-Tyne.*
A	1910	MacAlister, Donald Alexander, A.R.S.M., F.G.S. 26 *Thurloe Square, South Kensington, London, S.W.*
A	1902	McGrigor, George Duncan, F.R.G.S. *Penlee, Alexandra Road, Penzance, Cornwall.*
A	1908	McLintock, William Francis Porter, B.Sc. *The Royal Scottish Museum, Edinburgh.*
A	1902	Maitland, Andrew Gibb, C.E., F.G.S. Government Geologist. *Geological Survey, Perth, Western Australia.*
L	1881	Mallet, Frederick Richard, F.G.S., F.C.S., F.I.C. 20 *King's Avenue, Ealing, London, W.*
A	1907	Mears, James Bartholomew, L.R.C.P., L.R.C.S. (Edin.). *Leuchars, Fifeshire.*
A	1902	Mennell, Frederic Philip, F.G.S. 49 *London Wall, London, E.C.*
L	1876	Merry, J. S. *Swansea, South Wales.*
L	C	Miers, Sir Henry Alexander, M.A., D.Sc., F.R.S. Principal of the University of London. 23 *Wetherby Gardens, London, S.W.*
A	1912	Morgan, Arthur Henry, A.M.I.C.E., M.I.M.M. Superintendent of the *Ruby Mines, Mogok, Upper Burma.*
L	1876	Morris, James. 28 *Brynymôr Crescent, Swansea, South Wales.*
A	C	Müller, Hugo, Ph.D., LL.D., F.R.S. 13 *Park Square East, Regent's Park, London, N.W.*
L	1880	Pearce, Richard, Ph.D., F.G.S. 6 *Beach Lawn, Waterloo, Liverpool.*
L	1899	Pollard, William, M.A., D.Sc., F.G.S., F.C.S. *Oakfield, Hitchin, Hertfordshire.*

Year of Election.

A 1891 Pope, William Jackson, M.A., M.Sc., F.R.S. Professor of Chemistry in the University of Cambridge. *Holmesdale, Brooklands Avenue, Cambridge.*

A 1910 Porter, Miss Mary Winearls. 76 *Banbury Road, Oxford.*

L 1887 Prior, George Thurland, M.A., D.Sc., F.R.S. Keeper of Minerals in the *British Museum* (*Natural History*), *Cromwell Road, London, S.W.*

L 1908 Raisin, Miss Catherine Alice, D.Sc., F.L.S. *Bedford College, York Place, Baker Street, London, W.*

A 1903 Rastall, Robert Heron, M.A., F.G.S. *Christ's College, Cambridge.*

A 1913 Rogers, Austin Flint, A.M., Ph.D. Associate Professor of Mineralogy and Petrography, *Leland Stanford Junior University, Palo Alto, California, U.S.A.*

A 1876 Rudler, Frederick William, I.S.O., F.G.S. *Ethel Villa, Tatsfield, Westerham, Kent.*

A 1902 Russell, Arthur Edward Ian Montagu. *Swallowfield Park, Reading.*

A 1912 Schaller, Waldemar Theodore, Ph.D. *United States Geological Survey, Washington, D.C., U.S.A.*

A 1908 Schröder, Robert. 17 *Leopoldstrasse, Heidelberg, Germany.*

L 1876 Scott, Robert Henry, M.A., D.Sc., F.R.S. 6 *Elm Park Gardens, London, S.W.*

A 1903 Scrivenor, John Brooke, M.A., F.G.S. Geologist to the Federated Malay States. *Kuala Lumpur, Federated Malay States.*

A 1884 Seligmann, Gustav. 6 *Neustadt, Coblenz, Rhenish Prussia.*

A 1908 Shand, Samuel James, D.Sc., Ph.D. Professor of Geology, *Victoria College, Stellenbosch, South Africa.*

A 1912 Simpson, Edward Sydney, B.E., F.C.S. Chemist, Geological Survey of Western Australia. 61 *Mount Street, Perth, Western Australia.*

L 1897 Smith, George Frederick Herbert, M.A., D.Sc., F.G.S., F.R.A.S. *British Museum* (*Natural History*), *Cromwell Road, London, S.W.*

A 1911 Smith, Herbert Gladstone, B.Sc., A.R.C.S., F.G.S. Demonstrator of Geology, *Imperial College of Science and Technology, South Kensington, London, S.W.*

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A	1910	SMITH, Walter Campbell, M.A., F.G.S. *British Museum (Natural History), Cromwell Road, London, S.W.*
A	C	SOLLY, Richard Harrison, M.A. *Hôtel Britannia, Cadenabbia, Lago di Como, Italy.*
A	1894	SPENCER, Leonard James, M.A., F.G.S. *British Museum (Natural History), Cromwell Road, London, S.W.*
A	1883	TEALL, J. J. Harris, M.A., LL.D., D.Sc., F.R.S. Director of the Geological Survey of Great Britain and of the Museum of Practical Geology. *The Museum*, 28 *Jermyn Street, London, S.W.*
A	1903	THOMAS, Herbert Henry, M.A., B.Sc., F.G.S. Geological Survey of England. *The Museum*, 28 *Jermyn Street, London, S.W.*
L	1877	TRECHMANN, Charles Otto, J.P., Ph.D., F.G.S. *Hudworth Tower, Castle Eden, Co. Durham.*
A	1891	TUTTON, Alfred Edwin Howard, M.A., D.Sc., F.R.S. *Duart, Willowby Park, Yelverton, South Devon.*
A	1913	WALKER, Thomas Leonard, M.A., Ph.D., F.G.S. Professor of Mineralogy and Petrography in the *University of Toronto, Canada.*
L	1894	WATTS, William Whitehead, M.A., M.Sc., Sc.D., F.R.S. Professor of Geology in the *Imperial College of Science and Technology, South Kensington, S.W.*
A	1913	WAY, Rev. John Pearce, D.D. *Moorlands, Exmouth.*
L	1895	WEBB, R. C.
L	1901	WESTON, Digby St. A. P., Lieutenant R.N. 132 *Cromwell Road, London, S.W.*
L	1876	WILLS, Joseph Lainson, F.C.S. *Care of Stifel Union Brewery, St. Louis, Missouri, U.S.A.*
L	1896	WILLS, Louis.
L	C	WOODWARD, Charles J., B.Sc., F.G.S. *The Lindens, St. Mary's Road, Harborne, Birmingham.*
A	1902	YOUNG, Alfred Prentice, Ph.D., F.G.S. *Care of Messrs. Grindlay & Co.*, 54 *Parliament Street, London, S.W.*

SOCIETIES, INSTITUTIONS, ETC.

To which the Publications of the Mineralogical Society are sent.

(Those sending Publications in Exchange are marked with an asterisk.)

LONDON: Royal Society, *Burlington House, W.*
Geological Society „ „
Chemical Society „ „
British Museum (Natural History), *South Kensington, S.W.*
*Museum of Practical Geology, 28 *Jermyn Street, S.W.*
*Imperial Institute, *South Kensington, S.W.*
*Institution of Mining and Metallurgy, *Salisbury House, London, E.C.*

OXFORD: Department of Mineralogy, University Museum.

NEWCASTLE-ON-TYNE: *North of England Institute of Mining Engineers.

TRURO: *Royal Institution of Cornwall.

HULL: Yorkshire Naturalists' Union. (*T. Sheppard, The Municipal Museums, Hull.*)

LIVERPOOL: *Geological Society, *Royal Institution.*

EDINBURGH: Royal Society.
*Geological Society, *India Buildings, George IV Bridge.*

GLASGOW: University of Glasgow.
*Geological Society, 207 *Bath Street.*

DUBLIN: Royal Irish Academy, 19 *Dawson Street.*

PARIS: *Société française de Minéralogie, *Sorbonne.*

BRUSSELS: Société belge de Géologie, de Paléontologie et d'Hydrologie.

LIÉGE: *Société géologique de Belgique.

LEIPZIG: *Zeitschrift für Krystallographie und Mineralogie. (*Dr. Stefan Kreutz, Basztowa 3, Krakau, Galicia, Austria.*)

STUTTGART: Neues Jahrbuch für Mineralogie, &c. (*Schweizerbart'sche Verlagshandlung*).

BERLIN: Zeitschrift für praktische Geologie. (*Prof. Max Krahmann, Berlin NW 40, Neues Tor 1.*)

MUNICH: Technische Hochschule.

HALLE: K. Leopoldinisch-Carolinische Deutsche Akademie der Naturforscher.

VIENNA: *K.-K. Naturhistorisches Hofmuseum, *Burgring.*
K.-K. Geologische Reichsanstalt.
*Tschermak's Mineralogische und Petrographische Mitteilungen. (*Prof. F. Becke, Mineralogisches Institut der Universität.*)

UPSALA: *Kongl. Universitets-Biblioteket.
HELSINGFORS: Administration des Mines.
ST. PETERSBURG: Mineralogical Society.
ROME: *Ufficio Geologico, *Via Sta. Susanna.*
NAPLES: *Società Reale, Accademia delle Scienze Fisiche e Matematiche.
PISA: *Società Toscana di Scienze Naturali.
*Il Nuovo Cimento. (*A. Battelli.*)
PADOVA: *Rivista di Mineralogia e Cristallografia. (*Prof. R. Panebianco, The University.*)
BUCAREST: Institut Géologique de Roumanie.
SYDNEY: *Royal Society of New South Wales.
*Australian Museum.
WELLINGTON: New Zealand Institute.
BULUWAYO: *Rhodesia Scientific Association, *P. O. Box* 240.
CAPE TOWN: *South African Association for the Advancement of Science, *P. O. Box* 1497.
KIMBERLEY (South Africa): Alexander McGregor Memorial Museum.
NEW BRUNSWICK: Department of Mines, Nova Scotia.
WASHINGTON (D. C.): *United States Geological Survey.
Smithsonian Institution.
NEW YORK: *American Institute of Mining Engineers, 29 *West 39th Street, New York City.*
NEW HAVEN (Conn.): *American Journal of Science.
PHILADELPHIA (Penn.): Academy of Sciences.
BALTIMORE (Maryland): Johns Hopkins University.
CHICAGO: University of Chicago (Journal of Geology).
LANCASTER (Penn.): Economic Geology, 41 *North Queen Street.*
BERKELEY (California): University of California.
MANILA (Philippine Islands): *Bureau of Government Laboratories.
BUENOS AYRES: *Sociedad Científica Argentina.

PROCEEDINGS

OF THE

MINERALOGICAL SOCIETY.

EXCERPT MINUTES OF COUNCIL MEETING.

Held in the Apartments of the Geological Society, June 17, 1913, *at* 5 *p.m.*

Dr. A. E. H. Tutton, F.R.S., President, in the Chair.

Prof. Thomas Leonard Walker and Prof. Antonio de Barros Barreto were elected Ordinary Members of the Society.

The death of Dr. K. J. V. Steenstrup, Honorary Member, was announced.

The following changes in the list of Officers and Council were approved for recommendation to the Members of the Society: Messrs. Fleischmann, Hilton, Russell, and Teall, in place of the four retiring Members of Council (Messrs. Barker, Gordon, Pearce, and Thomas).

The President was requested to send on behalf of the Council a letter of congratulation to Professor Groth on his seventieth birthday.

GENERAL MEETING.

Held in the Apartments of the Geological Society, June 17, 1913, *at* 5.30 *p.m.*

Dr. A. E. H. Tutton, F.R.S., President, in the Chair.

Twenty-nine Members and five Visitors were present.

The elections of Prof. T. L. Walker and Prof. A. de Barros Barreto as Ordinary Members of the Society were confirmed.

Mr. W. L. Bragg exhibited and described a series of lantern-slides illustrating crystal-structure as revealed by Röntgen radiation [see Proc. Roy. Soc., 1913, ser. A, vol. 89, p. 248], and other slides illustrating the same subject were exhibited by Dr. Tutton.

The following papers were then read:—

1. The crystal-habit of Topaz from New Brunswick, Canada: by Mr. H. V. Ellsworth (p. 39).

2. The meteoric stone of Baroti, Punjab: by Dr. G. T. Prior (p. 22).

Specimens of kämmererite from Unst, Shetlands, sent by Dr. A. W. Gibb, were exhibited.

EXCERPT MINUTES OF COUNCIL MEETING.

Held in the Apartments of the Geological Society, November 11, 1913, *at* 5 *p.m.*

Dr. A. E. H. Tutton, M.A., F.R.S., President, in the Chair.

The Rev. Dr. John Pearce Way and Prof. Richard Percival Devereux Graham were provisionally elected Ordinary Members of the Society.

The following were selected as the dates of meeting for the year 1914: Tuesdays, January 27, March 17, June 16, and November 10, the last to be the Anniversary Meeting.

The draft Annual Report of Council, submitted by the Secretary, was approved.

A vote of thanks was passed to Dr. G. F. Herbert Smith for sending notices of the meetings of the Society to 'Nature', 'The Geological Magazine', 'The Mining Journal', and 'Centralblatt für Mineralogie'.

A proposed exchange of publications with the Liverpool Geological Society was accepted.

ANNIVERSARY MEETING.

Held in the Apartments of the Geological Society, November 11, 1913, *at* 5.30 *p.m.*

Dr. A. E. H. Tutton, M.A., F.R.S., President, in the Chair.

Thirty members and two Visitors were present.

The elections of the Rev. Dr. J. P. Way and Prof. R. P. D. Graham to the Ordinary Membership were confirmed.

The scrutineers reported that forty-six voting-papers had been returned, and that the list as nominated by the Council was approved, namely:

President. A. E. H. Tutton, M.A., D.Sc., F.R.S.

Vice-Presidents. Prof. H. L. Bowman, M.A., D.Sc., F.G.S.
A. Hutchinson, M.A., Ph.D., F.G.S.

Treasurer. Sir William P. Beale, Bart., K.C., M.P., F.G.S., F.C.S.

General Secretary. G. T. Prior, M.A., D.Sc., F.R.S.

Foreign Secretary. Prof. W. W. Watts, LL.D., Sc.D., F.R.S.

Editor of the Journal. L. J. Spencer, M.A., F.G.S.

Ordinary Members of Council.

W. Barlow, F.R.S.
F. H. Butler, M.A., A.R.S.M., L.S.A. (Lond.)
T. Crook, A.R.C.Sc.I., F.G.S.
J. P. De Castro, M.A., F.I.C., F.C.S.
F. N. A. Fleischmann, M.A., F.C.S.
Prof. H. Hilton, M.A., D.Sc.
Sir Thomas H. Holland, K.C.I.E., D.Sc., F.R.S.
B. Kitto, F.I.C., F.G.S.
Prof. A. Liversidge, M.A., LL.D., F.R.S.
Arthur Russell.
G. F. Herbert Smith, M.A., D.Sc., F.G.S.
J. J. Harris Teall, M.A., LL.D., D.Sc., F.R.S.

The following ANNUAL REPORT OF COUNCIL was read:—

During the Session 1912–13 four meetings have been held (by kind permission) in the Apartments of the Geological Society, Burlington House, W., at which seventeen papers were read. At the June meeting Mr. W. L. Bragg exhibited and described lantern-slides illustrating crystal-structure as revealed by Röntgen radiation. Two numbers of the Journal, viz. No. 76 published in December and No. 77 in July, have been issued. These contain sixteen papers and a sixth list of new mineral names compiled by Mr. Spencer, together with notes and reviews. The cost of one of the two plates illustrating the paper on the El Nakhla meteorite by Dr. Prior in No. 76 was defrayed by the author; and the block for the text-figures in the paper 'On the temperature of optical uniaxiality in gypsum' by Messrs. Hutchinson and Tutton was lent by Mr. Hutchinson.

The balance-sheet of the year ending December 31, 1912, shows that the financial position of the Society continues to be satisfactory. The assets (exclusive of the Library and stock of the Journal) amounted to £851 19*s.* 2*d.*, and the liabilities to £16 7*s.* 3*d.* The value of the stock invested in the names of the Trustees of the Society was on that date £738 14*s.* 0*d.*, corresponding to £13 13*s.* 7*d.* for each Life-Member.

During the Session 1912–13 the Society has lost by death one Honorary Member, Dr. K. J. V. Steenstrup. Two Honorary Members (Prof. F. Wallerant and Prof. F. W. Clarke) and eight Ordinary Members have been elected. The total number of members on November 10, 1913, was 143, of whom eighteen are Honorary. Of the Ordinary Members fifty-four have compounded for their annual subscription.

At the International Geological Congress held at Toronto, Prof. H. L. Bowman acted as a delegate to represent the Society.

The Council has to congratulate the Society on its continued prosperity.

On the motion of Mr. Campbell Smith, seconded by Dr. Drugman, the Report was adopted.

A vote of thanks to the Council of the Geological Society for permission to meet in the Apartments of the Society was carried.

The dates of meeting for 1914, proposed by the Council, were approved.

The following papers were then read :—

1. A crystalline basic copper phosphate from Rhodesia: by Dr. A. Hutchinson and Mr. A. M. Macgregor.

2. On the meteoric stone of Wittekrantz, South Africa: by Dr. G. T. Prior (p. 28).

3. On the remarkable similarity in chemical and mineral composition of chondritic meteoric stones: by Dr. G. T. Prior (p. 33).

4. Notes on the minerals occurring in the neighbourhood of Meldon, near Okehampton, Devonshire: by Mr. Arthur Russell.

5. On a calcium-iron-garnet from China: by Mr. J. B. Scrivenor (p. 51).

Specimens of minerals from Meldon, Devonshire, were exhibited by Mr. A. Russell and by Mr. F. P. Mennell; and a specimen of orbicular granite from Co. Donegal was shown by Mr. F. N. A. Fleischmann.

EXCERPT MINUTES OF COUNCIL MEETING.

Held in the Apartments of the Geological Society, January 27, 1914, *at* 5 *p.m.*

Dr. A. E. H. Tutton, F.R.S., President, in the Chair.

Messrs. Arthur William Rogers, Alexander Scott, and Arthur Edward Victor Zealley were provisionally elected Ordinary Members of the Society.

Messrs. J. P. De Castro and W. Campbell Smith were elected Auditors of the Accounts for the year ending December 31, 1913.

Proposed exchanges of publications with the University of Hong-kong, and the Transylvanian National Museum were accepted.

A proposal made by Sir Thomas Holland that abstracts of the papers to be read should be issued with the notices of meetings was discussed.

GENERAL MEETING.

Held in the Apartments of the Geological Society, January 27, 1914, *at* 5.30 *p.m.*

Dr. A. E. H. Tutton, F.R.S., President, in the Chair.

Thirty Members and five Visitors were present.

The elections of Messrs. A. W. Rogers, A. Scott, and A. E. V. Zealley to the Ordinary Membership of the Society were confirmed.

The following papers were read:—

1. The genetic classification of rocks and ore deposits: by Mr. T. Crook (p. 55).

2. An apparatus for grinding crystal-plates and prisms: by Messrs. H. H. Thomas and W. Campbell Smith (p. 86).

3. Uniaxial Augite from Mull: by Mr. A. F. Hallimond (p. 97).

4. Lawsonite from the central Coast Ranges of California: by Prof. A. F. Rogers.

Specimens of spherulitic felsite from the Esterel Mountains, France, were exhibited by Dr. J. Drugman.

EXCERPT MINUTES OF COUNCIL MEETING.

Held in the Apartments of the Geological Society, March 17, 1914, *at* 5 *p.m.*

Dr. A. E. H. Tutton, M.A., F.R.S., President, in the Chair.

The audited Balance-sheet for the year ending December 31, 1913, was approved, and instructions were given for it to be inserted in the Minutes and to be published in the next issue of the Journal.

Resolved to give a donation of £5 towards the expenses of publication of the International Annual Tables of Constants.

Mr. Arthur Holmes was provisionally elected an Ordinary Member of the Society.

The deaths of Prof. H. Rosenbusch, Honorary Member, and Mr. C. R. Lindsey, Ordinary Member, were announced, and the Foreign Secretary was requested to send a letter of condolence to the widow of Prof. Rosenbusch.

A letter was read from the President of the Sixth International Congress of Mining, Metallurgy, Engineering, and Practical Geology inviting the Society to take part officially in the proceedings to be held in London on 12–17 July, 1915.

GENERAL MEETING.

Held in the Apartments of the Geological Society, March 17, 1914, *at* 5.30 *p.m.*

Dr. A. E. H. Tutton, M.A., F.R.S., President, in the Chair.

Twenty-two Members were present.

The election of Mr. A. Holmes as an Ordinary Member of the Society was confirmed.

The following papers were read :—

1. On an occurrence of Bornite nodules in shale from Mashonaland: by Mr. F. P. Mennell (p. 111).

2. Augite from Bail Hill, Dumfriesshire : by Mr. A. Scott (p. 100).

3. On a sulpharsenite of lead from the Binnenthal : by Dr. G. T. Prior.

4. On Gmelinite and Chabazite from Co. Antrim : by Dr. G. T. Prior.

Specimens of Heulandite and Prehnite from Wales were exhibited by Mr. Arthur Russell.

MINERALOGICAL SOCIETY.

ABSTRACT OF RECEIPTS AND PAYMENTS FROM JANUARY 1 TO DECEMBER 31, 1913.

Receipts.	£	s.	d.	£	s.	d.
Balance from 1912				60	6	3
Subscriptions—(1) current	57	14	0			
(2) arrears	6	6	0			
(3) advances	3	3	0			
				67	3	0
Entrance fees and composition				10	10	0
Sale of publications—						
By Publishers	40	0	10			
By G. Savigar	2	0	11			
				42	1	9
Dividends on Investments				24	1	2
				£204	2	2

Payments.	£	s.	d.	£	s.	d.
Printing Magazine (No. 76)	17	8	8			
Authors' copies	4	8	6			
Illustrations	4	12	6			
				26	9	8
Printing Magazine (No. 77)	31	11	8			
Authors' copies	4	19	0			
Illustrations	4	2	0			
				40	12	8
Miscellaneous Printing—				7	4	6
Editor's Honorarium (1912)				10	10	0
G. Savigar for care of stock of Publications (1912)				1	1	0
Porter's Fee at meetings (1912)				1	0	0
R. Jones, manipulating lantern					2	6
Postage and Parcels—						
Magazine	4	12	8			
Charge for 500 wrappers		14	0			
G. Savigar (1912)		8	8			
Hon. Secretary (1912)		8	9			
Hon. Treasurer (1912)		7	7			
				6	11	8
Investments—						
Dividends	23	15	2			
Life Compositions, etc.	35	0	0			
Brokers' fees on above		6	0			
				59	1	2
Bank Charges					1	3
Balance at Bank	51	3	5			
„ in Office		4	4			
				51	7	9
				£204	2	2

Examined and compared with the vouchers, and found correct.
5 *February*, 1914.

(*Signed*) J. PAUL DE CASTRO } Auditors.
W. CAMPBELL SMITH }

BALANCE SHEET.

DECEMBER 31, 1913.

LIABILITIES.	£	s.	d.
Owing for Editor's Honorarium (1913)	10	10	0
„ G. Savigar for care of stock of Publications (1913)	1	1	0
„ Do. for postage (1913)		14	6
„ Hon. Secretary for postage (1913)		6	0
„ Do., fee paid for lantern		10	0
„ Hon. Treasurer for postage (1913)		7	7
Excess of assets over liabilities	875	11	1
	£889	0	2

ASSETS.	£	s.	d.	£	s.	d.
Balance at Bank	51	3	5			
„ in Office		4	4			
				51	7	9
Consols (£1078 4*s.* 3*d.*, valued at £71)				765	10	0
Sale of Publications (1913)—						
Owing from Publishers	55	16	7			
„ G. Savigar		10	10			
				56	7	5
Arrears of Subscriptions valued at				15	15	0
				£889	0	2

The amount owing for No. 78 of the Magazine is not included in the above liabilities, the amount not being yet received.

The number of Life Members on December 31 was fifty-four.

The stock of Publications and the value of the Library are not included in the above assets. (*Signed*) W. P. BEALE,
Hon. Treasurer.
Feby. 1914.

THE MINERALOGICAL MAGAZINE

AND

JOURNAL OF

THE MINERALOGICAL SOCIETY.

No. 79. JULY, 1914. Vol. XVII.

The genetic classification of rocks and ore deposits.

By T. Crook, A.R.C.Sc. (Dublin), F.G.S.
Scientific and Technical Department, Imperial Institute.

[Read January 27, 1914.]

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1. General Remarks.

DURING the last decade there has been no lack of controversy on the subject of rock classification, but the dispute has concerned gneous rocks almost entirely. Petrography has been threatened by an ffort to reduce it to an independent science of igneous rocks, and in

consequence of this there has been a tendency to neglect its wider aspects. Important as igneous rocks are, their formation is less well understood than is that of some other sub-groups of rocks; moreover, they constitute one only of some six or seven sub-groups, and it is the business of petrography as a science to deal with these rocks as a whole. The student of petrography should be encouraged to take this wider view. He should look at these different sub-groups of rocks in their proper geological perspective, and approach the study of the classification of igneous rocks with a knowledge of the principles that are applicable to the classification of rocks as a whole.

The discussion concerning the classification of ore deposits has proceeded on independent lines, and in a more well-balanced manner than has that of rocks. With ore deposits, as with rocks generally, genetic principles have triumphed; but the application of these principles to rocks long preceded their application to ore deposits. In recent years it has become apparent that the fundamental requirements for the classification of rocks and ore deposits are essentially the same; and in view of the identity of their interests, both subjects are treated in this paper.

The aims of this paper are: To define the basis of genetic classification; to give a brief historical account of classification on genetic-geological principles; to point out defects in the present system of arrangement; and to suggest an alternative scheme of grouping that is in closer accord with geological and genetic principles.

2. Rocks.

(*a*) *Historical Review.*

To understand the present situation as regards the genetic grouping of rocks it is helpful to note the growth of the ideas involved; and for that reason a brief historical sketch is here given. To begin this it is necessary to go back to the very beginnings of modern geology, for the study of the processes by which rocks are formed long preceded the detailed study of rock slices by means of the polarizing microscope.

James Hutton (1785).—To Werner and his school (the Neptunists), whose views dominated geology towards the end of the eighteenth century and at the beginning of the nineteenth, all rocks, with the exception of volcanic ejectamenta, were aqueous in origin; and rocks were grouped by them according to age. It was Hutton's statement of the Plutonist doctrine in his 'Theory of the Earth' (Trans. Roy. Soc., Edinburgh, 1788, vol. i; read in 1785) that laid the foundations of a study of crustal

processes and rock genetics. In that work Hutton established conclusively the distinction in mode of origin between igneous and sedimentary rocks, and pointed clearly, though with some exaggeration of its significance, to the existence of a third great group of thermally altered rocks to which Lyell afterwards gave the name 'metamorphic'.

By this study of rocks in relation to crustal processes, Hutton instituted what we may call the genetic-geological basis, in place of the age basis, for the broad grouping of rocks; and it is therefore to his 'Theory of the Earth' that the initiation of the modern threefold grouping of rocks must be traced.

Sir Charles Lyell (1833).—By introducing the term metamorphic to describe those sedimentary rocks that had been reconstituted by thermodynamical changes, Lyell definitely established a group of metamorphic rocks. It is a rather singular fact, however, that in his notions concerning the broad grouping of rocks Lyell did not put the emphasis on processes. He attached much more importance to place of deposition than to mode of origin. This is shown by the fact that he grouped plutonic (not volcanic) rocks with metamorphic rocks under the name 'hypogene'; and he appears to have anticipated a much wider use for the term hypogene than for the term metamorphic, for he remarks: 'We divide the hypogene rocks then into unstratified or plutonic and the altered stratified. For these last the term "metamorphic" may be used. The last-mentioned name need not, however, be often resorted to, because we may speak of hypogene strata, hypogene limestone, hypogene schist; and this appellation will suffice to distinguish the formations so designated from the plutonic rocks' ('Principles of Geology,' 1833, and later editions). The same feature is illustrated by the fourfold division of rocks which he adopted, and in which plutonic and volcanic rocks are treated as independent groups ('Elements of Geology,' 1838, and later editions). It is thus noteworthy that Lyell's use of the term hypogene was not strictly genetic, for he used it only with reference to rocks and not with reference to processes.

In 'The Student's Lyell' Judd retains Lyell's broad grouping on the basis of place of formation, and adopts the term epigene (used previously by Geikie in application to surface processes) as a group name for volcanic and sedimentary rocks, thus:—

Epigene	Volcanic.
	Sedimentary.
Hypogene	Metamorphic.
	Plutonic.

Cordier, von Leonhard, Brongniart, and Naumann (1800–50).—It was during the early part of the nineteenth century that there developed the fashion—not yet quite extinct—of studying rocks as if they were minerals, independently of their connexion with the science of geology. The most notable of the early specialists in the study of rock specimens, the petrographers proper of some authors, were Cordier, von Leonhard, and Brongniart, to all of whom rocks, like minerals, were things to be studied *per se* and classified accordingly. To them, consequently, the mode of origin of a rock was a matter of no importance, and their classifications were based entirely on intrinsic characters.

It was natural enough that the study of rocks should at that time take such a turn, in order that a knowledge of their intrinsic characters should be acquired. Indeed, Wernerian ideas of rock origins were very much alive at that time, and the feelings developed in the famous controversy were so strong that the peace-loving petrographer, who was ambitious to know more concerning the composition of rocks, was left with no alternative but that of making his classification independent of genetic data.

Gradually, however, the Huttonian conception of rock origins won its way. Lyell's 'Principles' and 'Elements' had not yet appeared when von Leonhard issued his 'Charakteristik der Felsarten' in 1823, and Brongniart his 'Classification et caractères minéralogiques des roches' in 1827; but after the appearance of Lyell's books there can be no doubt as to the change they wrought, and by the middle of the century genetic ideas were again active in petrography. Thus Naumann, in his 'Lehrbuch der Geognosie' (1849), looked at rocks from a much wider standpoint, and dealt with petrogenesis, though his classification of rocks was not genetic.

H. Coquand (1857).—It was not until 1857 that there appeared a work devoted specially to petrography in which the genetic mode of grouping was followed. In that year Coquand issued his 'Traité des roches', in which he adopted a threefold division of rocks into igneous, aqueous, and metamorphic types, and his subdivision of these was as far as possible genetic. Coquand's 'Traité' stands out prominently as the first purely petrographic work in which an attempt is made to correlate rock groups with formative agents and processes, up to the limits of available knowledge concerning those processes, using other data such as mode of occurrence and intrinsic characters only where the genetic data are uncertain, or to distinguish rocks arising from one and the same process.

B. von Cotta (1862).—In the first edition of his 'Gesteinslehre', published in 1855, von Cotta classified rocks in fourteen groups on the basis of their intrinsic characters. When, however, in 1862, he issued the second edition of this work, he followed Coquand's example, and divided rocks into three broad genetic groups, viz. eruptive, sedimentary, and metamorphic. It was presumably Lawrence's translation into English of the second edition of von Cotta's 'Gesteinslehre' that established this mode of division among English petrologists, though doubtless the fact that it harmonized with the Huttonian traditions fostered by Lyell was not without its significance.

David Forbes[1] (1867).—In a paper entitled 'The Microscope in Geology' (Popular Science Review, 1867) Forbes adopted a twofold division of rocks into primary or eruptive and secondary or sedimentary. The terms *primary* and *secondary* are here used quite independently of geological chronology. Primary rocks (of all ages) might be called "ingenite or subnate rocks" (i.e. such as are born, bred, or created within or below), whilst the term "derivate rocks" would be appropriate for the latter, since directly or indirectly they are all derived from the destruction of the former' (op. cit., p. 358). In making this suggestion Forbes was evidently thinking of mode of origin rather than place of formation as the proper basis of his twofold division, but he did not deal logically with the metamorphic rocks, since he referred to these separately, and failed to indicate how they were to be classified. It is perhaps worth

[1] David Forbes was one of the pioneers of microscopical petrography. As early as 1852 he had begun his rock studies with the microscope, working at slices which were cut for him by Oschatz of Berlin, who appears to have entered this field of activity independently of Sorby. This was some ten years prior to the date when Sorby, sitting with Zirkel on the Drachenfels, explained to him the advantage of examining rock slices microscopically, and described to him how slices were prepared. It is not unfair to the memory of Sorby to say that, though he was perhaps without equal as a master of the technique of rock-slicing, he was no match for Forbes as a petrographer. It is indeed doubtful if, during the late fifties and early sixties, there was anywhere a worker who had made such a wide study of this subject as Forbes. He was a practised observer in this line of work, thanks almost entirely to his own foresight and enthusiasm, before Zirkel had realized its value. He did not limit his microscopical investigation to slices; for he tells us that 'thin splinters of rocks and powdered fragments, mounted in Canada balsam, may also be examined with advantage'. His paper on 'The Microscope in Geology' was indeed a valuable early scientific contribution to microscopical petrography, excellently illustrated with coloured and other drawings of rock slices, and embodying work done at a time when there was no literature on the subject bearing on the broad outlook which he entertained.

mentioning that Forbes used the term metamorphism in a wide sense, as Naumann had already used it, and as it has been used since by many writers, notably by Van Hise.

G. H. Kinahan (1873).—In his 'Handy Book of Rock Names', published in 1873, Kinahan developed the suggestion put forward by Forbes, and produced a more scientific twofold division of rocks. He adopted the terms 'ingenite' and 'derivate', using them much in the same senses as Forbes had indicated; but instead of treating metamorphic rocks as abnormal types, he put the thermo-dynamically metamorphosed sedimentary rocks with the eruptives under the 'Ingenite' group, and put all other rocks into the 'Derivate' group. It is evident enough, however, that Kinahan was led to do this by his geological instinct rather than by any logical principles of classification; for in dealing with the metamorphic rocks he writes: 'The metamorphic sedimentary rocks belong indeed to the Derivate order; but being compelled to make a selection, we place them under the Ingenite, as the arrangement seems to involve the least inconvenience. They are Ingenite rocks, as they have been in a certain sense *formed below*, yet their materials were previously derived from the destruction of other rocks.' Thus Kinahan, prompted by considerations of convenience (!) rather than by any definite principles of genetic grouping, chose a mode of grouping which in its broad features is in accordance with a scientific and geological grouping of processes. One exclaims at his considerations of convenience, because it is on these very grounds that others have regarded it necessary to make a threefold grouping, with metamorphics as an independent group. It is interesting to interpret Kinahan's twofold grouping in the light of Geikie's later twofold grouping of crustal processes. It is also interesting to compare it with the choice made by Kalkowsky, who adopted a twofold division but treated the metamorphosed sediments differently (see below).

Sir Archibald Geikie (1879).—In his article on Geology in the 'Encyclopaedia Britannica' (1879 and later editions), and in his 'Text-book of Geology' (1882 and later editions), Geikie adopts the usual threefold division of rocks into igneous, sedimentary, and metamorphic. On the other hand, he adopts a twofold division of crustal processes, namely: 'I, Hypogene or plutonic action—the changes within the earth, caused by original internal heat and by chemical action. II, Epigene or surface action—the changes produced on the superficial parts of the earth, chiefly by the circulation of air and water set in motion by the sun's heat' ('Text-book of Geology', 1903 edition, vol. i, p. 262).

We see, then, that whereas Lyell used the term hypogene for rocks which had assumed their characteristics below the surface or deep-seatedly and did not apply it to processes, Geikie uses it for processes and does not apply it to rocks. The difference between these two uses is a rather serious one, for, using the term as Geikie does, volcanic action is hypogene, from which we should infer that volcanic rocks are hypogene, although they assume their characteristics under surface conditions, and were for that very reason excluded by Lyell from his hypogene rocks.

The conclusion of this matter seems to be that it is necessary to distinguish between the mode of origin of a rock (i.e. the formative processes involved in the production of its chief characteristics) and the place of formation (i.e. the situation under which it has assumed those characteristics). It appears that neither of the terms hypogene and plutonic can legitimately be used in such a way as to cover volcanic action. Further, Geikie's definition of the term epigene does not allow of its application to volcanic rocks as Judd has applied it (see p. 57). It also appears that terms applied to processes according to their deep-seated or superficial origin ought to apply to rocks irrespective of the position in which their characteristics are developed.

E. Renevier (1880).—An interesting genetic scheme of classification was that proposed by Renevier[1] in a paper read before the Geologists' Association in London in 1880, descriptive of the arrangement adopted by him for the rock collection of the Lausanne Museum. According to Renevier, 'Ce qu'il y a d'essentiel dans les roches, c'est leur origine, ou leur mode de formation,' and he adopted five groups, as follows: (1) *Deuterogenous* rocks, or sediments of mechanical origin; (2) *Organogenous* rocks, or sediments of organic origin; (3) *Hydatogenous* rocks, or chemical deposits of aqueous origin, including vein deposits; (4) *Pyrogenous* or igneous rocks; and (5) *Cryptogenous* rocks, of doubtful origin, including crystalline schists.

K. A. Lossen (1884).—In his paper 'Ueber die Anforderungen der Geologie an die petrographische Systematik' (Jahrb. k. Preuss. Geol. Landesanst. u. Bergakad. for 1883, 1884), Lossen made a strong defence of the geological basis of classification, and advocated a twofold division of rocks on morphological data (see also Zeits. Deutsch. Geol. Gesell., 1872, vol. xxiv, pp. 784 and 785). The massive and stratified rocks, according to Lossen, constitute two distinct and natural types of deposit.

[1] E. Renevier, 'A petrographical (*sic*) classification of rocks,' Proc. Geol. Assoc., 1880, vol. vi, p. 426. For a fuller account see 'Classification pétrogénique,' Bull. Soc. Vaud., 1882, vol. xviii, p. 93.

No third type corresponding to metamorphic rocks exists; and since these were originally formed as either massive or stratified rocks, they were not allowed by Lossen to constitute an independent group. Much as Lossen protested against the genetic element in rock classification, however, it is clear from his reasoning that his conceptions of massive and stratified rocks, though expressed in morphological terms, are not free from the influence of genetic ideas. His twofold division is essentially the same as the primary and secondary or eruptive and sedimentary of certain older authors; and the slenderness of his case against genetic data can perhaps be best seen by a comparison of his divisions with those adopted by Kalkowsky (see below).

Lossen's views had great influence on Rosenbusch and other petrographers. In his 'Mikroskopische Physiographie der massigen Gesteine' (1877 and later editions), Rosenbusch followed Lossen. In this work he treats the metamorphic rocks imperfectly in connexion with the 'massive' rocks, not because they are 'massive' rocks, but because he regards it as convenient to deal with contact metamorphism when describing intrusive rocks. This is an obviously unscientific method of procedure, and it may be assumed that Rosenbusch himself recognized this fact, when, in his 'Elemente der Gesteinslehre' (1898 and later editions), he adopted the threefold division into eruptive rocks, stratified rocks, and crystalline schists.

E. Kalkowsky (1886).—In a work entitled 'Elemente der Lithologie', published in 1886, Kalkowsky proposed what he claimed to be a genetic division of rocks into 'anogene' and 'katogene' rocks (p. 29): 'Gesteine entstehen also entweder, indem das Material dazu sich von unten nach oben bewegt oder umgekehrt von oben nach unten; erstere Gesteine wollen wir anogene, die letzteren katogene nennen. Dieselben Gruppen der Gesteine hat man auch mit anderen Namen belegt, von denen eruptiv und sedimentär so ziemlich dasselbe bedeuten, aber nicht den Ursprung des Materiales, den Anlass zur Bildung, sondern nur die äusseren Vorgänge bei der Bildung andeuten.' The curious fact about this twofold grouping by Kalkowsky is its similarity in all except names to that of Lossen, who disclaims all recognition of the genetic basis of grouping. Kalkowsky follows Lossen in refusing to recognize a third group of metamorphic rocks. He regards the genetic basis as useful only for the purpose of making a main twofold division, and he puts metamorphic rocks in the 'katogene' group.

C. R. Van Hise (1904).—In his 'Treatise on Metamorphism' Van Hise deals elaborately with many aspects of rock genesis. He divides the

earth's crust into (1) an outer 'katamorphic zone' in which metamorphism results in the disintegration of complex compounds to produce simpler ones; and (2) an inner 'anamorphic zone' in which the changes are characterized by the formation of complex minerals at the expense of simpler ones. The 'katamorphic zone' is subdivided into (*a*) an outer belt of weathering and (*b*) an inner belt of cementation, the ground-water level defining the limit between these two belts.

It is often useful, when dealing with metamorphism, to distinguish between anamorphic and katamorphic changes as defined by Van Hise. Much less real are the 'zones' in which these changes are supposed to take place; for anamorphic changes are not necessarily deep-seated, and katamorphic changes are not necessarily superficial. There appears to be no accordance between anamorphic and katamorphic changes and the operation of formative agents and processes geologically considered. Important as pressure is, it is much less significant than heat and solution effects as a cause of mineralogical changes among rocks as we know them. The paramount importance of igneous intrusions as agents of metamorphism, the effects of which are usually anamorphic but sometimes katamorphic, and the importance of thermal effects even in 'regional' metamorphism, are facts not readily accommodated by the zonal divisions of Van Hise.

It is by these considerations that we must explain the failure of his crustal zones to provide a basis for the geological or genetic classification of either rocks in general or metamorphic rocks in particular. It was, however, not for the study of rocks and their classification, but for the study of the changes they undergo, that Van Hise suggested this way of looking at the earth's crust; though its bearing on the broad features of rock origins makes a notice of it necessary in giving an historical review on the subject of genetic classification.

Conclusion.—From the foregoing review it is seen that the subject of the broad genetic grouping of rocks has been handled in a more or less incomplete manner by many authors. Place of deposition has been confused with mode of origin. Formative processes have been considered apart from their bearing on genetic classification, and genetic groupings of rocks have been made without recognition of the fact that such groupings should be based on a geological analysis of processes. There has been throughout no recognition of a definite genetic method, and there has been no satisfactory co-ordination of rock-grouping and process-grouping such as the broad facts of rock genesis distinctly suggest.

(*b*) *The genetic-geological basis of classification.*

The data available for the classification of rocks are of two sorts, namely (1) Intrinsic, i.e. the data that can be obtained from a study of the specimens themselves, without reference to the mutual relations of the masses which they represent, or to the conditions under which those masses have been formed; and (2) Extrinsic, i.e. the data that relate not merely to the characters observed in a study of specimens *per se*, but to the mutual relations and modes of origin of the masses which they represent. The intrinsic data comprise the mineral and chemical composition of specimens, and their textural characters. The extrinsic data comprise the modes of origin, relative ages, modes of occurrence, and morphological features of the masses which the specimens represent.

The most important differences of opinion among authorities on the subject of rock classification arise from differences in mental bias concerning the relative importance of these two kinds of data. On the one hand, there are those who have a mineralogical and chemical bias, and who, naturally enough, choose intrinsic data as the basis of grouping. This school aspires to the establishment of descriptive petrography as a separate branch of study, based not upon geological but upon physical and chemical principles. It is not to be wondered at that the extremists of this school should regard petrography as a sort of museum study, aiming chiefly at the cabinet-grouping of specimens on the most expedient basis, which basis may be as artificial as is necessary in the interests of expediency. On the other hand, there are those whose bias is geological, and to whom rocks, unlike minerals, are things to be grouped in accordance with geological principles, and not simply in accordance with chemical and physical principles. By this school it is considered necessary that petrography should be naturalistic in scope.

Those who select intrinsic data as the basis of grouping put forth two claims which it is necessary to examine. One of these is that a system of classification should be free from the influence of theories of origin. This claim is indeed made by all who are opposed to the genetic basis of classification. It was put forth by some of the earlier petrographers; it has been advocated in recent years by L. Fletcher, who has applied the mineral-textural basis to rocks as a whole ('An introduction to the study of rocks,' British Museum Guide-Book, 1895); and by W. Cross on behalf of the quantitative-chemical basis for igneous rocks (see 'Geological versus petrographical classification of rocks,' Journ. Geol., 1898, vol. vi. See also 'Review of the development of systematic petro-

graphy in the nineteenth century,' Journ. Geol., 1902, vol. x). Among geologists, the claim that 'classification should be as free as possible from a leading theory' was made by De la Beche, who divided rocks on a morphological basis into (1) stratified and (2) unstratified ('Geological Manual,' 3rd edition, 1833). It was also strongly advocated by Lossen (see p. 61), whose plea was for a geological basis of grouping, and whose two chief groups did not differ materially from those of De la Beche.

The second claim made in defence of the choice of intrinsic data is that made by Cross, namely, that in a study of rocks it is necessary to distinguish 'between the formal unit and the rock substance of that unit', which means that, for the purpose of classification, rocks should be treated like minerals and considered as specimens rather than as parts of the earth's crust. This view is, of course, inseparable from the choice of intrinsic data as the basis of classification, and Cross has pushed it to its logical issue. He claims candidly that petrography as a science is the study of specimens *per se*, and that a *petrographical* classification, based on intrinsic data, should be treated separately from a *petrological* classification based on extrinsic data. Until, however, it has been admitted that petrography as thus defined has any *raison d'être* as a separate science, it seems unnecessary to admit this distinction between the terms petrology and petrography.

Neither of the above claims can be substantiated on geological grounds; and the answer to them appears to be given adequately enough by a consideration of the proper definition of the term rock, and by the inference, arising out of that definition, that the scientific basis of petrography is geological.

The term rock, properly considered, embodies a geological concept. It is as the architectural elements of the earth's crust, rather than as aggregates of minerals or chemical constituents, that rocks are best and most fundamentally considered; and, unlike a mineral, a rock has no scientific significance except in so far as it can be regarded as representative of the mass from which it has been detached. The mere description and classification of rocks as specimens, apart from any consideration of their origin and occurrence, can scarcely be made to constitute a science, in however quantitative a manner this operation be carried out; and if petrography is to fulfil any scientific purpose, it is necessary that it should link itself on to some definite body of scientific principles.

Now petrography offers splendid scope for the application of chemical and physical principles, but practically none for their establishment or advancement. There is, indeed, little fear that chemists or physicists

will ever claim petrography as a branch of their sciences. What a study of rocks does establish and advance, and that in a very substantial manner, is a knowledge of geological principles. The necessity of petrography for the elucidation of these principles, and its needlessness for the elucidation of any other body of scientific principles, affords one very good explanation of the inherent weakness and consequent failure of schemes of rock classification that are non-geological in character; for on looking back over the century or so of history that petrography has now made, one finds that no non-geological scheme of classification has been successful. It has proved to be impossible, on the basis of intrinsic data, to secure a grouping that will harmonize with geological principles. To obtain such a grouping, we have to appeal to extrinsic data.

As regards extrinsic data, it seems scarcely worth arguing that age relations are useless as a basis of petrographical classification. More significant are morphological features and modes of occurrence; but though these have played and still play an important part as a basis of grouping, it is chiefly as a makeshift that they are tolerated, and as soon as they can with any satisfaction be made to do so, they give place to data connected with the mode of origin of the rocks, i.e. genetic data. Of all the extrinsic data available for rock classification, it is the genetic that give fullest play to the geological principles concerned in rock studies; and it is presumably for this reason that genetic data have always maintained an important place in rock classification, though never more so than at the present day.

As already mentioned, however, there have been, and still are, those who oppose genetic data on the ground that the origins of rocks are to some extent matters of theory. The history of petrography affords very little encouragement to those who hold this view, and present tendencies afford still less. If the experience of the past and the tendencies of the present teach us anything at all about classification, they show clearly that no system can be useful and acceptable unless it helps, and accommodates itself to, the prevailing theories of rock origins. As far as possible, therefore, a system of rock classification should be genetic.

In this paper, genetic data are regarded as comprising only that portion of extrinsic data relating to the action of formative agents and processes. Some writers have used the term in a less definite way, as including also certain other extrinsic data. It is, moreover, assumed in this paper that, since a genetic classification is one based on a study of formative processes, it is desirable first of all to decide upon a scientific

grouping of these processes, and then to make a corresponding grouping of rocks.

It should be noted that a system of classification can be geological without being genetic, and conversely, it can be genetic without being geological. But by expressing the genetic data in a geological way it is possible to secure a scheme of classification that is eminently suited to geological requirements, and one that satisfies the needs of both science and practical utility.

From these considerations, then, we arrive at the following conclusions, in which the features of chief importance in the classification of rocks may be briefly summarized:

(1) In accordance with the view that the term rock embodies a geological concept, the classification of rocks should be as broad-based and complete as possible; it should pass in review the whole of the accessible rocks (mineral deposits) of the earth's crust.

(2) The highest end to be attained in rock classification is the correlation of types with formative processes. The mode of grouping should therefore be genetic, and as far as possible in accordance with a scientific grouping of processes. Data other than genetic should only be used as a temporary arrangement, or to distinguish rocks arising from one and the same process.

(3) The mode of grouping should be geological as well as genetic; and for this purpose the grouping of the formative processes should be in accordance with their disposition and operation in the earth's crust.

(4) The supreme objection to the grouping of rocks on the basis of intrinsic data is, that such a mode of grouping cannot be made to accommodate the data of dynamical geology. On the other hand, the genetic method of classification does not dispose of the necessity for intrinsic data, but uses these data as a basis for defining types of rocks, and the different varieties of any particular type. Genetic classification, therefore, finds a place for all kinds of data, geological, mineralogical, and chemical; whilst it conforms to and accommodates the facts and theories of dynamical geology, and by so doing stimulates the growth of the science of which it forms a part. Only by a due recognition of this scientific function of petrography is it possible to explain the history and present tendencies of rock classification.

(*c*) *The conventional threefold grouping of rocks—its merits and defects.*

From the historical point of view, one of the most interesting facts about rock classification is the way in which the custom of making

a threefold division into igneous, sedimentary, and metamorphic has persisted. This mode of grouping is based on extrinsic data. It was, as we have seen, adumbrated by Hutton, and it seems to be the only scheme that meets with favour at the present day. To the early geologists by whom it was fostered, rocks had no meaning except as tectonic masses. It was not adopted by the early petrographers, who strove to establish groupings on the basis of intrinsic data. In later years, and even after the institution of the practice of rock slicing, Zirkel, Lossen, Rosenbusch, and others opposed it, but to no purpose. Petrographers have thus adopted the threefold grouping, not because they like it, but apparently because necessity has forced it upon them.

The explanation of this fact seems to be that the conventional grouping of rocks as igneous sedimentary, and metamorphic possesses the two prime virtues required of a system of rock classification: it is geological and genetic. Though based on genetic-geological principles, however, it is not a scientific embodiment of those principles. It is, indeed, generally admitted that this mode of grouping is prompted more by convenience than by devotion to principles of classification. Not only is it unscientific in this respect. It is open to the still more serious objection that it does not allow of completeness of grouping, an objection which is specially applicable where the term 'metamorphic' is used in its restricted sense. Let us now look briefly at these defects of the conventional threefold grouping.

Igneous rocks.—Concerning igneous rocks, in so far as these are regarded as the congealed material of the magmas proper, and are treated independently of the exudation-products of these magmas, there can be no doubt that they constitute a distinct genetic sub-group.

Sedimentary rocks.—Strictly speaking, the term sediment should mean detrital sediment. It was probably for this reason that Lyell and other geologists applied the terms aqueous and sub-aqueous to rocks deposited in water. The term sedimentary is, however, now used to include deposits from surface solutions as well as detrital deposits. Inaccurate as this usage is, it does not cause any inconvenience unless we wish to make provision for subterranean solution deposits. It is then we realize that, when the solutions responsible for these deposits originate at the surface, they should be grouped genetically with surface solution deposits, leaving an independent sub-group for the mechanical sediments or detrital deposits.

Metamorphic rocks.—Lyell applied the term metamorphic to hypogenetically altered sedimentary rocks, i.e. those that had suffered a

transformation of type under deep-seated conditions. Except for the extension of its meaning to igneous rocks that have been similarly altered, most authors have adhered to Lyell's restricted usage, in spite of the fact that this usage is at variance with the full literal significance of the term. The obvious inconvenience of this restricted use of the term is that it excludes or misplaces a number of important types of alteration products, and makes completeness of grouping on anything like a scientific basis practically impossible.

It is, therefore, not surprising that many authors have been unable to resist the temptation to use the term 'metamorphic' in a wider sense, including under it rocks that have suffered a transformation of type under the influence of atmospheric changes and descending solutions. Some of the older writers used the term in this wider sense, but of all writers it is Van Hise who, in his 'Treatise on Metamorphism', has given this wider usage its fullest scope. Unfortunately for the student of rocks, however, that author limits his study almost entirely to the nature of metamorphic changes from a physical and chemical standpoint, and says very little about the really petrographical aspect of the subject.

Van Hise defines metamorphism as any change in any kind of rock. His metamorphic rock is one that has been altered by any agency whatever. From the standpoint of those who wish to retain the conventional threefold grouping, the serious drawback of this sweeping definition is that it makes all rocks metamorphic; for all rocks, as we know them, have arisen from changes in the constitutions of pre-existing rocks. This definition, therefore, goes too far; but where is the line to be drawn? There has hitherto been no satisfactory definition of the term. Either it is made too incomplete or too comprehensive in its meaning, and it seems from this standpoint that the adoption of a separate group of metamorphic rocks, in the sense implied by the conventional threefold grouping, is undesirable.

There is another way in which this question as to the desirability of separate main groups of sedimentary and metamorphic rocks may be approached. The division of rocks into igneous, sedimentary, and metamorphic is essentially genetic. As already postulated, however, if a genetic system of classification is to be scientific, it must pre-suppose a logical classification of formative processes. The scheme in question does not correspond to any such logical grouping of processes; and from the genetic standpoint it is therefore unsatisfactory, even if, for the purpose of classification, some arbitrary definitions of the terms igneous,

sedimentary, and metamorphic could be agreed upon that would give this mode of grouping the needed quality of completeness.

Whether, therefore, we approach the consideration of this threefold division of rocks from the standpoint of its incompleteness, or of the feasibility of suitable definitions, or from the standpoint of genetic principles, we arrive at the conclusion that it does not satisfy the requirements of a scientific system of rock classification. What is the alternative?

(*d*) *The grouping of rocks in relation to processes.*

Before dealing with the alternative, it is necessary to consider briefly how rock types should be grouped in relation to the processes that have influenced their characters. This consideration is made necessary by the fact that some authors have adopted a method of grouping in which metamorphic types are classified with the rocks from which they have been derived. On this principle, a mica schist should be classified as a shale, and a hornblende schist as a dolerite, where it is known that these rocks have been produced by the metamorphism of shale and dolerite respectively. In Kalkowsky's mode of grouping (see p. 62) this principle was adopted. Again, J. Walther (Compte rendu, Congrès géologique international, for 1897) regards rocks as possessing primary or original characters that were given to them when they were first formed, and secondary characters that have been developed by alteration. This idea is, of course, also involved in the conventional threefold grouping; but, like Lossen and others who preceded him, Walther suggests the abolition of the metamorphic group, and makes it one of his principles of classification that the altered rocks are to be grouped with their original types. He makes four groups of original rocks, as follows: I Mechanical, II Chemical, III Organic, and IV Volcanic rocks. It is perhaps noteworthy that these correspond to Renevier's first four groups (see p. 61).

This view, expressed in such definite terms by Walther, implies (1) that certain types are to be regarded as original, (2) that it is possible to ascertain in any given case what the original type was, and (3) that original types should be grouped in accordance with the processes that have determined their existing characteristics, whereas altered types should be grouped in accordance with processes that determined their characteristics in some pre-existing state. It is difficult to see how any of these propositions can be sustained on either a geological or a genetic

or any other scientific basis of classification. At any rate, they seem to be quite at variance with sound genetic principles.

Now it cannot be denied that rocks owe their characteristics to the processes by which they have been formed. It is these processes that have conditioned the mineral composition and texture of rocks as we know them. The operation of these processes is more or less continual, and there is no such thing as permanent stability of type. From the genetic standpoint, therefore, every rock is to be regarded as the product of a series of changes, only the last term or two of which is known to us; and if so, which of the many processes that have influenced the type of the rock is to be regarded as of chief importance in connexion with its classification?

The only acceptable answer to this question seems to be that, in relation to any given rock, those processes are of chief importance that have developed its dominant characteristics, i.e. that have developed those intrinsic characters by a study of which, in relation to its origin, the type of the rock is ascertained. The interminable nature of the cycle of changes, by which the characteristics of rocks are affected, renders quite impracticable the suggestion that altered rocks should be classified according to their original condition. Indeed, all rocks arise from changes in pre-existing masses, and nowhere do we find them in their original condition. Hence the only practicable genetic method is that of grouping a rock according to the nature of the process that has stamped upon it the characteristics that mark it as a type.

(*e*) *An alternative grouping on a genetic-geological basis.*

On the basis laid down in the foregoing generalizations, we are now in a position to decide upon an alternative and more scientific grouping of rocks. The principles that should govern the arrangement are—(1) it must be made in accordance with a geological grouping of processes; (2) the grouping must be determined by the nature of the process that, in any given case, has conferred upon the rock its type characteristics. This brings us to consider how processes can be best classified.

If we look at the earth's crust as a whole, it is almost impossible, from a geological point of view, to avoid a twofold main grouping of processes; for these processes seem to divide naturally into (1) those that originate in internal causes, and operate deep-seatedly in the earth's crust or from within outwards; and (2) those of external origin, operating superficially or from without inwards. This division of processes is practically the same as that involved in the twofold division of rocks

made by Kinahan, following a suggestion made by Forbes (see p. 60). The terms 'ingenite' and 'derivate', introduced by Forbes and used by Kinahan, are, however, obviously ill-formed and unsuitable for the two groups of processes referred to above.

It will be noticed that this twofold division of crustal processes is also much the same as that made by Geikie (see p. 60), but it seems inadvisable to apply the terms 'hypogene' and 'epigene' used by him. In the first place, Geikie's use of the term 'hypogene' is not the same as Lyell's, and it might very properly be urged that this term should be defined, as it is defined in Murray's Oxford Dictionary, with the meaning that Lyell intended it to carry. The terms 'epigene' and 'epigenetic' are in a still more serious predicament, since the latter has been, and still is, used antithetically to the term 'syngenetic' by writers on ore deposits, to describe a deposit the age of which is subsequent to that of the rocks in which it occurs. Indeed, its use in this sense with reference to ore deposits is now so extensive and popular that its previous geological usage as defined by Geikie (see also Murray's Dictionary) appears to have been almost lost sight of. Again, as we have already seen, the term 'epigene' has been used in a still different sense by Judd (see p. 57), who uses it antithetically to the term 'hypogene', using the latter term in the Lyellian sense, but using both terms in relation, not to processes, but to place of deposition.

Moreover, two good terms are available for the two groups of processes to which reference has been made, viz. *endogenetic* (originating within) and *exogenetic* (originating without). The terms 'endogene' and 'exogene' have long been used by German and French geologists, chiefly as the equivalents of 'eruptive' and 'sedimentary' respectively. They were used in these senses by some of the earlier geologists, notably by A. von Humboldt in his 'Cosmos' (1844). In the English edition of that work the terms 'endogenous' and 'exogenous' were used; and the use of these terms in this broad geological sense has thus priority over certain more limited usages now in vogue in petrology. As these terms are not required for use as equivalents of 'eruptive' and 'sedimentary', it seems permissible to use them as here required, in the forms *endogenetic* and *exogenetic*, firstly in application to the processes defined above, and secondly in application to the rocks produced by the operation of those processes, irrespective of place of deposition. The form *endogenetic* appears to be new, but *exogenetic* is already in use as here defined (see Murray's Oxford Dictionary).

Endogenetic processes fall into three natural subdivisions, viz. those

associated with (1) fusion and the direct crystallization of the fused (igneous) masses, (2) exudations arising from the action of these fused intrusive masses, and (3) thermal and thermo-dynamic alterations unaccompanied by fusion and exudation effects. Some may choose to make an additional subdivision for purely dynamical processes that result in the formation of crush-breccias and other types in which texture is affected by simple crushing and trituration without any alteration in mineral constitution; but to others this will seem unnecessary, and it would appear to do no violence to the principles of genetic classification to group such types with their uncrushed equivalents.

Exogenetic processes are best subdivided, from a geological standpoint, with reference to the phenomena of weathering and denudation, and this mode of subdivision entails a distinction between weathering residues and transported materials. The transported materials are deposited in part mechanically and in part from solution, whilst deposition from solution is effected in part from surface waters and in part from waters descending into the crust. Subaerial plant accumulations and their products form an independent subdivision.

On the basis of the classification of processes thus outlined, we get the following corresponding scheme of rock classification :—

I. ENDOGENETIC ROCKS, formed by processes of internal origin, which processes operate deep-seatedly or from within outwards. High-temperature effects constitute the prevailing characteristic, and the water taking part as an agent is partly of magmatic origin.
   1. IGNEOUS ROCKS.
   2. IGNEOUS EXUDATION PRODUCTS:
      (*a*) Contact impregnations and metasomatized rocks, including pneumatolysized rocks.
      (*b*) Hydrothermal vein rocks.
      (*c*) Solfataric deposits.
   3. THERMO-DYNAMICALLY ALTERED ROCKS, but unfused and unmodified by exudations.

II. EXOGENETIC ROCKS, formed by processes of external origin, which processes operate superficially or from without inwards. These rocks are formed at ordinary or comparatively low temperatures, and the water taking part in their formation is of atmospheric origin.
   1. WEATHERING RESIDUES.
   2. DETRITAL ROCKS, comprising aeolian, alluvial, and marine sediments, loose or cemented.

3. Solution deposits, loose or cemented.
   (i) *Surface-solution deposits*:
      (*a*) Organic deposits.
      (*b*) Inorganic deposits.
   (ii) *Descending-solution deposits*:
      (*a*) Certain vein deposits.
      (*b*) Metasomatized rocks.
4. Subaerial plant accumulations and their products.

A grouping of rocks on these lines has the advantage of completeness. It makes possible a complete survey of crustal processes, with a geological classification of which it is in harmony; and it has thus a sound genetic-geological basis. It is, perhaps, not quite so simple as the conventional threefold grouping; but it is more scientific, and it avoids many difficulties that confront us if we wish to retain sedimentary and metamorphic groups. Moreover, the scheme here proposed should not give any difficulty to a student who has taken as seriously as he should the study of formative processes which, in the shape of physical geology, usually precedes that of petrology.

There is, of course, ample scope for discussion as to the best way of subdividing the two main groups. It is impossible within the limits of this paper to consider the many points which such a discussion involves, or to enter into details. Two or three features of note, however, may be referred to.

There are strong genetic reasons at present for recognizing a sub-group of rocks characterized by the presence of exudation products, as distinct from the igneous rocks and their segregation products. These exudation products, in the form of gases, vapours and solutions arising from the action of a magma, produce important effects in the aureole of enclosing rock, and in the porous rocks and fissures through which they find their way towards the surface. Until the problem of the genetic grouping of igneous rocks has been satisfactorily solved, it seems best to make a separate sub-group for rocks characterized by these exudation products. Ultimately, however, it may be found preferable to group them more intimately with the igneous rocks, each distinctive type of magma being grouped together with the exudation products peculiar to it.

Connected with this question is that of the subdivision of the rocks styled 'metamorphic' in the restricted sense. The practice of distinguishing contact-metamorphosed and regionally metamorphosed rocks is one that has been widely adopted, but one for which, in the usually

accepted sense of these terms, there is no warrant from a genetic standpoint. Contact metamorphism is in many cases merely a local and small-scale manifestation of the thermal or thermo-dynamical processes to the effects of which, on a wider scale, the name regional metamorphism is given. The only difference is that in the contact case the source of heat is visible in the shape of an intrusive mass, whereas in the regional case the source of heat is less obvious, and the effects more widespread. Of far greater importance is the distinction, not involved in the terms contact and regional as used by petrologists, between masses that have been substantially modified by exudation products and masses that have not been so modified; for except in so far as an invaded rock has borrowed material from the intrusive, there is no material difference between contact-metamorphosed and regionally metamorphosed types.

According to the arrangement here proposed, those contact-metamorphosed rocks characterized by the presence of exudation products form part of a special sub-group, and a third sub-group of endogenetic rocks comprises those in which thermal or thermo-dynamical alterations have taken place without fusion and without any substantial addition of new material.

As regards igneous rocks, it is not the writer's intention to enter into the question of their genetic classification in this paper. Moreover, it is as yet a matter of opinion whether there exists a sufficiently good theory concerning magmatic processes to serve as a substantial basis for the genetic grouping of igneous rocks; and attempts at such a grouping are perhaps undesirable until more conclusive evidence is available concerning the origin of magmas, the relative importance of differentiation and absorption as modifying factors, and the mechanism of intrusion.

Present tendencies, however, are towards the adoption of a genetic system, and it seems pretty certain that no system will prove satisfactory that is not genetic; for it is true of igneous rocks in particular, as it is of rocks in general, that their intrinsic characters have been conditioned by formative processes in such a way as to make these characters, considered alone and apart from their genetic bearings, unavailable as a basis of grouping consistent with geological requirements.

The quantitative basis of classification is clearly at variance with the genetic basis, and igneous rock affinities cannot be stated in terms of oxide percentages or of any conventions based thereon. In the opinion of the present writer nothing could be more decisively erroneous than the view, adopted by the school of quantitative-chemical classifiers, that the chemical composition of igneous rocks, as expressed by the analysis

of specimens, is the most fundamental feature concerning them. The chemical composition of a specimen depends entirely on its mineral composition; and the relation between the mineral and the chemical composition is such that although the chemical composition can be inferred from a knowledge of the mineral composition, the converse is not true. That is why, in the quantitative-chemical system, it is impossible to codify analyses in terms of natural mineral composition. The 'norm' of this system is an unnatural expression of a chemical analysis of a rock specimen. It has no meaning apart from that specimen, and it cannot possibly be invested with a genetic significance.

The natural mineral composition of rocks, on the other hand, may be allowed to have a genetic significance, and when its relation to magmatic conditions is properly understood, the correlation of the natural mineral composition of igneous rocks and magmatic processes will be possible. It is these processes that are fundamental, and that, studied in relation to natural mineral composition, mode of occurrence, and texture, should be made the basis of grouping among igneous rocks.

Pending the establishment of such a genetic basis, there appears to be no legitimate alternative to a classification based on mode of occurrence and mineral-textural features, combining these naturalistic data in such a way as to secure the best advantage from the genetic-geological point of view.

3. Economic Mineral Deposits.

(*a*) *The study of ore genesis inseparable from that of rock genesis.*

Ore deposits are rock masses in which occur one or more metalliferous minerals in sufficient quantity to make them useful as sources of metals. This definition can be extended to deposits of economic minerals generally, i.e. an economic mineral deposit is a rock mass in which occur one or more useful minerals in such quantity that it is practicable to extract them for use in the arts. Any one who faces the facts fairly will find it impossible to escape from this petrological definition of an ore deposit.

In some instances an economic mineral in itself constitutes a rock. Masses and beds of iron ore, chromium ore, manganese ore, corundum, rock salt, apatite, and numerous other instances could be quoted. More commonly, however, the economic mineral is, from a quantitative standpoint, a comparatively insignificant constituent of the rock in which it occurs; but in all cases the deposit as a whole is essentially a rock. Indeed, there are all possible gradations between instances in which economic minerals in themselves form the chief part of a rock mass, and

those in which they are disseminated through a large amount of useless rock matrix.

One important end is attained by this way of looking at ore deposits: it shows the fundamental value of petrology in a study of these deposits. If the recognition of this fact has been slow in growth, the petrographers are to blame; for had vein deposits and other types of economic mineral deposits received adequate scientific treatment at their hands, there would doubtless have been a quicker, and by this time a fuller recognition of the almost inseparable connexion that exists between rock genetics and ore genetics, and of the mutual aid that these studies can afford.

It is certainly unscientific to allow an igneous dyke to rank as a rock, and to deny that rank to a vein deposit, especially when we take into consideration the fact that a vein deposit is often of far greater dimensions than a dyke. The recognition of this fact by petrologists has at most been extremely feeble—witness the name *quartz rock* given to vein quartz, of hydrothermal origin, associated with granites; and also the admission of the hydrothermal origin of certain pegmatite veins. Even Weinschenk ('Grundzüge der Gesteinskunde,' 1902), who is comparatively liberal in these matters, tells us, after having dealt with the formation of pegmatites, that 'Die übrigen Neubildungen der postvulkanischen Perioden haben für die Gesteinskunde an sich weniger Interesse, ihre Besprechung gehört vielmehr in die Lagerstättenlehre.' (op. cit., 1. Teil, p. 114.)

Coupled with this point of view, there exists among certain petrographers an objectionable practice of naming as independent types every new combination of silicate minerals among igneous rocks, without any reference whatever to the scale of magnitude displayed by the occurrence. This practice is in itself perhaps not absurd, but it is made to appear so by the fact that, associated with the practice, there is a lack of any sense of proportion in rock studies. It is hardly likely that such an unscientific attitude of mind will prove permanent, and one may safely predict that petrography is destined to broaden its sympathies and rationalize its outlook.

Ore deposition is, indeed, even from the petrological standpoint, an important and not merely a trifling incident in the process of change that is continually affecting the rocks of the unstable earth's crust; and whether it has taken place *pari passu* with the formation of the more ordinary rock in which the ore deposit occurs, or subsequently, it is one of several causally related incidents that need to be considered together.

The origin of ore deposits is thus inseparably bound up with the origin of rocks. It almost follows as a matter of course that the best genetic grouping of ore deposits should correspond closely with that of rocks: and if, for reasons already stated, it is desirable to have a genetic-geological arrangement for rocks, it is for the same reasons also desirable to have a genetic-geological grouping of ore deposits.

(*b*) *Historical Review.*

We have seen that, from the beginning of modern geology, the broad grouping of rocks has been made on a genetic basis; and in spite of much opposition from those who have held the view that petrography and rock classification should be independent of geology, the genetic method of classification has gradually strengthened its position.

With ore deposits, the origins of which it has been, and still is, less easy to establish, the genetic mode of grouping has on the whole been less successful; and grouping according to morphological data has been more widely adopted. Here again, as in the case of rocks, those who have fostered the morphological point of view have done so on the plea that classification should be free from the influence of theories of origin.

Werner was deeply interested in both rock genesis and ore genesis, and the influence of his petrological ideas on his views concerning ore deposits is very obvious ('Neue Theorie von der Entstehung der Gänge,' 1791). Even in Werner's time, the terms 'Lager' and 'Gänge' had been long associated with German mining tradition; and consistently with his way of classifying rocks on the basis of relative age, Werner made a sharp distinction between ore deposits corresponding to 'Lager' which had originated contemporaneously with the enclosing rock, and those corresponding to 'Gänge', which had been formed later. 'Die Gänge müssen von einzelnen Schichten des Gesteins, von mehr und weniger mächtigen Lagern des Gebirges, von Flözzen, Fällen und Stökken,—die insgesamt mit der Gebirgsart, in der sie sich befinden, und zu der sie gehören, einerlei Lage haben,—wohl unterschieden werden.' (op. cit., p. 4). This point is perhaps worth emphasizing, because the distinction of ore deposits according to their contemporaneous or subsequent formation in relation to the enclosing rocks has dominated German views on the grouping of ore deposits down to the present day, and is still regarded by some as the most fundamental distinction that it is possible to make. It has indeed been declared by nearly all writers to be a genetic distinction. In fact, however, it is based on relative age of deposit and

enclosing rock, and though it is non-morphological, and may perhaps be allowed to have had a genetic significance for the Wernerians, it can scarcely be allowed to have a definite genetic meaning to those who accept the Huttonian view that igneous rocks are of intrusive origin, and who believe that magmatic exudations are important agents in vein formation.

During the first half of the nineteenth century, the reaction against theoretical conceptions in the classification of ore deposits was even more pronounced than it was in the case of rocks. Von Cotta, who had been converted to the genetic view of grouping for rocks, resisted this view in the case of ore deposits, and adopted a morphological basis of grouping. He says: 'Ich theile aber alle Erzlagerstätten ihrer Form nach zunächst in regelmässige und unregelmässige. Die ersteren zerfallen wieder in Lager und Gänge, die letzteren in Stöcke und Impregnationen.' ('Die Lehre von den Erzlagerstätten,' 1859, part i, p. 2). His mode of grouping as (1) *Regular deposits* and (2) *Irregular deposits* is one that has had a considerable vogue. Another non-genetic mode of grouping of ore deposits that has been widely used is that adopted by J. D. Whitney ('Metallic wealth of the United States,' 1854), viz. (1) Superficial, (2) Stratified, and (3) Unstratified deposits. (See also 'A treatise on ore deposits,' by J. A. Phillips, 1884.) This arrangement is borrowed from geology, for it had been used much earlier by De la Beche and others in the classification of rocks.

Although these non-genetic schemes have enjoyed much favour, they have not altogether monopolized the field; and at the present time they have been largely ousted among serious students of ore deposits by genetic methods of grouping. The morphological basis of grouping was abandoned by von Groddeck (see 'Lehre von den Lagerstätten der Erze,' 1879; and Berg- u. Hütt. Zeit., 1885, p. 217). Von Groddeck's scheme is very interesting; in it he wedded the Wernerian conception of relative age for ore deposits to the Huttonian conception of rock grouping, thus: I, Deposits formed contemporaneously with the rocks in which they occur; (*a*) sedimentary, (*b*) eruptive. II, Deposits formed later than the rocks in which they occur; (*a*) those filling pre-existing spaces in rocks, (*b*) metamorphic deposits.

Divested of its main groups, this scheme of von Groddeck differs only from the threefold division into igneous, sedimentary, and metamorphic, which had already been adopted for rocks, by having an additional group for vein deposits, &c.[1]

[1] According to Pošepný, von Groddeck entertained the idea of a composite

Pošepný followed von Groddeck in the view that 'the principal genetic distinction is doubtless between deposits contemporaneous with the country rock and those subsequently formed in it' ('The Genesis of Ore Deposits,' Trans. Amer. Inst. Min. Eng., 1894 (for 1893), vol. xxiii, p. 205). Again, he states that 'we have two main groups of mineral aggregates: that of the rocks, and that which we will call comprehensively *the mineral deposits*. The minerals of the first group belong to it as native and original; those of the second are foreigners to the rock in which they occur. The two groups may therefore be designated as Idiogenous and Xenogenous respectively' (op. cit., p. 205). Later in the paper, however, he remarks: 'We distinguish, then, *Idiogenites*, or deposits contemporaneous in origin with the rock, from *Xenogenites*, the deposits of later origin, including not merely those of ores but mineral deposits in general; and to these we may add, in harmony with some older systems, the deposits of débris as a third class, *Hysterogenites* or latest formations' (op. cit., p. 211). Still later in his paper, when he comes to describe the different kinds of deposits, he groups them under four heads as follows: 1, Ore deposits in spaces of decission. 2, Ore deposits in soluble rocks. 3, Metamorphous deposits. 4, Hysteromorphous deposits.

It seems evident enough from these statements by Pošepný that his ideas on genetic classification were rather indefinite. His views are strongly reminiscent of von Groddeck's, but his scheme is less geological and decidedly less scientific. It does not correspond to any rational or definite grouping of processes, and it is not the strictly genetic system that it has been claimed to be.

Stelzner (see 'Die Erzlagerstätten,' by A. W. Stelzner and A. Bergeat, 1904) adopted a main grouping into primary and secondary deposits, a mode of grouping that was favoured by von Groddeck at first, but afterwards rejected by him. Stelzner also grouped the primary deposits into those formed contemporaneously with, and those formed subsequently to, the rocks in which they occur; and to these groups he applied the names 'syngenetic' and 'epigenetic' respectively. He was followed by R. Beck ('Lehre von den Erzlagerstätten,' 1901; see also 'The nature of ore deposits,' by R. Beck and W. H. Weed, 1905), and this mode of division, expressed in these terms, is now very widely adopted. Thus

classification in which 'he hoped to represent one standpoint by abscissae and the other by ordinates, so that the intersection would determine the type of deposit' (op. cit., infra, p. 201). This idea has been applied by F. H. Hatch in a semi-genetic scheme recently proposed by him (Presid. Address, Inst. Mining and Metall., London, March 1914).

Lindgren writes: 'Two genetic terms have, however, found general acceptance after their recent introduction by Stelzner and Beck. These terms are *syngenetic* and *epigenetic*' (Econ. Geol., 1907, vol. ii, p. 750).

This application of the terms 'syngenetic' and 'epigenetic' by Stelzner, Beck, and others, is a rather unfortunate one. The term 'epigenetic' had been already used in several different ways in geology, and it has now such a variety of meanings from a petrological standpoint that it seems inadvisable to use it unless some restriction of its meaning can be agreed upon. The term 'syngenetic' had also been used petrologically and in a different sense by von Gümbel before it appeared in connexion with the literature of ore deposits ('Geologie von Bayern; I. Grundzüge der Geologie,' by K. W. von Gümbel, 1884, p. 370).

A much more serious objection to the use of these terms in these senses is the fact that their significance is not truly genetic. Indeed, the use of the terms 'syngenetic' and 'epigenetic', as applied to the broad grouping of ore deposits by Stelzner and others, is a good example of the misuse of the term genetic. For instance, Beck and Weed, in adopting this mode of grouping, remark of their scheme that 'it entirely abandons form as a factor of importance, and is thus purely genetic' (op. cit., p. 3). Similar remarks, implying that the data of classification are necessarily either simply morphological or simply genetic, have been made by other authors.

We have seen, however, that *form* is not the only non-genetic factor that is made use of in classification. Contemporaneity or lack of contemporaneity in age of deposition between ore deposits and the rocks in which they occur, does not constitute genetic data. This factor, as already explained, has to do with relative age of deposit and enclosing rock, and is independent of the mode of origin or formative processes involved; for whether we consider the 'syngenetic' or the 'epigenetic' group, we find that each is necessarily made to include deposits arising from widely diverse processes. Thus ore deposits resulting from igneous activity may be either 'syngenetic' or 'epigenetic'; the 'syngenetic' group includes both igneous segregations and sedimentary deposits; and vein deposits are 'epigenetic' whatever may have been the origin of the solutions from which they have been deposited. One therefore demurs at the statement made very recently by W. Lindgren, that 'A convenient and fundamental classification divides mineral deposits into *syngenetic*, or those formed by processes similar to those which have formed the enclosing rock, and in general simultaneously with it, and *epigenetic*, or those introduced into a pre-existing rock' ('Mineral

Deposits', 1913, p. 140). Convenient it may be; whether it is fundamental or otherwise depends on the view one takes as to the proper basis of classification; but it is certainly not genetic; and it is quite time that the view involved in this mode of grouping, which has played such a conspicuous part in German schemes of classification, should be definitely recognized as Wernerian in origin, and should no longer be regarded as genetic.

Another scheme which has been described as genetic is that proposed by H. S. Munroe (see 'The Ore Deposits of the United States and Canada', by J. F. Kemp, 1900). Munroe divides deposits into those (1) *of surface origin, beds,* (*a*) mechanical, (*b*) chemical, (*c*) organic, (*d*) complex; and (2) *of subterranean origin,* (*a*) filling fissures and cavities formed mechanically, (*b*) filling interstitial places and replacing walls. His main divisions are thus essentially identical with the stratified and unstratified divisions of some other authors, and his scheme can scarcely be regarded as genetic, except in a very imperfect way.

Of the really genetic schemes of grouping, the more scientific are those proposed by Kemp, Weed, Van Hise, and Lindgren. Kemp (op. cit.) makes a threefold main division, viz.: I, Of igneous origin; II, Deposited from solution; and III, Deposited from suspension. He divides his solution deposits into (1) surface precipitations, and (2) disseminations in beds or sheets, the former having five and the latter eleven subdivisions.

W. Lindgren (see 'Mineral Deposits', 1913, p. 188) goes a step further than Kemp, and eliminates the geological factor altogether in making his main divisions, treating igneous bodies as solution deposits. His chief groups are as follows: I, Deposits produced by mechanical processes of concentration (temperature and pressure moderate); II, Deposits produced by chemical processes of concentration (temperature and pressure vary between wide limits)—(*a*) in bodies of surface water, (*b*) in bodies of rocks, (*c*) in magmas, by processes of differentiation.

W. H. Weed (Engineering and Mining Journal, 1903, vol. lxxv, p. 256) adopts five divisions, as follows: (1) Igneous, (2) Pneumatolytic, (3) Fumarolic, (4) Gas-aqueous deposits, (5) Meteoric waters, and these he subdivides elaborately.

These schemes proposed by Kemp, Weed, and Lindgren all fail to attach sufficient importance to the geological basis of grouping, though in this respect perhaps Weed's scheme errs least. None of them succeeds in securing, what it appears necessary to secure for ore deposits, a scheme of classification that will harmonize with the scheme adopted

for rocks. Petrological considerations would appear to furnish a safe control in these matters, and a genetic scheme for economic mineral deposits should, in its main features, hold for rocks generally. If we apply this test, the schemes of Kemp, Weed, and Lindgren are seen to be unsatisfactory.

More satisfying from the petrological point of view was the suggestion made by Van Hise (op. cit.), to group ore deposits simply as igneous, sedimentary, and metamorphic. If one takes the view emphasized in this paper, that ore deposits, and economic mineral deposits generally, are rocks, and that the study of these deposits has an essentially petrological basis, it seems inevitable that one should adopt a geological rather than a physico-chemical setting for the genetic data of classification in grouping ore deposits. The only question to be settled is, whether the threefold division, with a recognition of sedimentary and metamorphic groups, meets the requirements of the case.

(c) *An alternative grouping on a genetic-geological basis.*

The arguments already advanced against the recognition of sedimentary and metamorphic rocks as separate genetic groups, apply with added force in the case of ore deposits; and it is doubtless this fact that has prevented many from grouping these deposits in the same way as they group rocks.

Deposits arising from solutions of surface origin, as products of metasomatism due to descending solutions, and as precipitations in streams, lakes, and seas, have a much closer genetic affinity with one another than they have with detrital deposits. Further, from the standpoint of ore genesis it is difficult to avoid using the term metamorphism in a wide sense; but for genetic reasons products arising from the metamorphic action of solutions of surface origin cannot logically be grouped together with metamorphic products arising from the action of igneous intrusions. Again, the division into igneous, sedimentary, and metamorphic groups fails in the case of ore deposits, as it does with rocks, to make suitable provision for all types, and makes necessary the clumsy expedient of a miscellaneous group in which are placed such types of deposits as cannot conveniently be treated in any other way.

In brief, a threefold division of ore deposits into igneous, sedimentary, and metamorphic does not correspond to any logical grouping of formative processes, and both from the geological and genetic point of view it is unsatisfactory. The only geological way out of the difficulty appears to

be that of adopting a twofold grouping into *endogenetic* and *exogenetic* deposits, on the lines already outlined for rocks as a whole. The subdivisions of these two groups in the case of ore deposits, or economic mineral deposits generally, will necessarily follow pretty closely that already given for rocks, as for example in the following table:—

I. ENDOGENETIC DEPOSITS:
- 1. Igneous segregations.
- 2. Igneous exudations:
  - (*a*) Contact impregnations and metasomatic effects, including pneumatolytic deposits.
  - (*b*) Hydrothermal vein deposits.
  - (*c*) Solfataric deposits.
- 3. Deposits in thermo-dynamically altered rocks (unfused and unimpregnated).

II. EXOGENETIC DEPOSITS:
- 1. Weathering residues.
- 2. Detrital deposits (including placer deposits).
- 3. Solution deposits:
  - (i) *Surface solutions:*
    - (*a*) Organic deposits.
    - (*b*) Inorganic deposits.
  - (ii) *Descending solutions:*
    - (*a*) Certain vein deposits and other cavity infillings.
    - (*b*) Metasomatic and secondary enrichment deposits.
- 4. Subaerial plant accumulations and their products.

4. Summary.

In this paper economic mineral deposits are regarded as rocks, a view which makes unavoidable the inference that ore genesis is a part of petrology, and that any scientific system of genetic classification that applies to rocks should apply also to economic mineral deposits.

A consideration of fundamental principles shows that petrography has its scientific basis in dynamical geology, and that any genetic scheme of classification for rocks should also be a geological scheme. An appeal to historical considerations likewise shows that the requirements of science, as regards the classification of rocks, seem to lie in the direction of a scheme based on what may be called genetic-geological principles.

A scientific classification in accordance with these principles presupposes the possibility of a geological classification of formative agents

and processes. These processes fall into certain natural groups and sub-groups according to the way in which they operate on and modify the rocks of the earth's crust. Having decided on a definite geological grouping of formative processes in this way, the grouping of rocks with reference to the processes that have determined their type characteristics becomes possible, the rock-groups corresponding to process-groups.

The genetic classification of rocks and economic mineral deposits is thus essentially a classification of formative processes, and a correlation of these processes with the rock types the intrinsic characteristics of which they have developed. The use of intrinsic data and other non-genetic data in petrography finds its place in the definitions of rock types, but these definitions should be controlled by genetic and geological considerations.

Petrologists have for the sake of convenience, but with lack of wisdom, refused to regard most economic mineral deposits as rocks. This attitude on their part made possible, at a comparatively early date, an approximation to a sound genetic-geological scheme of grouping for rocks. The adoption of such a scheme for ore deposits was prevented by uncertainty as to the origin of subterranean solution deposits which fill an important place in ore genetics.

It has been known for a long time among petrologists that certain metalliferous vein deposits are genetically connected with igneous intrusions. The studies of recent years in ore genesis have largely extended the significance of solutions of deep-seated origin in connexion with ore deposition. There are, nevertheless, certain vein types which are known to arise from solutions of surface origin; and although the criteria for determining the origin of vein deposits are not fully established for all types, it seems permissible to adopt a genetic scheme in which processes are grouped geodynamically in two broad groups according to their internal or external origin in relation to the earth's crust. Such a scheme of division into *endogenetic* and *exogenetic* processes is adopted in this paper, and the subdivision is made in accordance with the geological action of the processes concerned.

The corresponding scheme for rocks may claim to be scientific. It is based on a well-defined genetic method. It comprehends all rock-forming processes, and finds a place for all types of rocks. The fact that uncertainty exists as to the nature of certain processes and the origin of certain types should be no bar to the adoption of such a scheme up to the limits of known facts and well-established theories, since it is one that will adapt itself to the progress of petrology.

An apparatus for cutting crystal-plates and prisms.

By Herbert H. Thomas, M.A., Sc.D., F.G.S.
Petrologist on H.M. Geological Survey; and

W. Campbell Smith, M.A., F.G.S.,
Assistant in the Mineral Department of the British Museum.

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THE apparatus to be described has been designed for the cutting of parallel plates and of prisms of crystallized substances in any required direction. The authors have endeavoured to design a small apparatus, simple in construction and easy to manipulate, which at the same time will be capable of yielding results of sufficient accuracy for most optical work on minerals. Several instruments have been devised with the same objects in view, notably those of E. A. Wülfing, G. Halle, and F. Stöber. The well-known cutting and grinding goniometer of Dr. Tutton is an instrument of an entirely different class.

The apparatus designed by Wülfing [1] in 1901 consists of a tripod, two legs of which are formed by movable screws, the third leg being the crystal itself. By means of the two screws the crystal, set on a suitable holder, can be brought into any desired position with respect to a grinding-lap. In practice, Wülfing showed that this apparatus was capable of yielding very accurate results but, theoretically, the fact that the grinding of the crystal is constantly shortening the third leg of the tripod necessitates frequent corrections and presents many disadvantages.

In 1889 Wülfing had devised another apparatus [2] in which the adjustments were similar to those in his present (1901) model, but the third

[1] E. A. Wülfing, 'Ueber einen vereinfachten Apparat zur Herstellung orientirter Krystallschliffe.' Neues Jahrbuch Min., 1901, vol. ii, pp. 1–22.

[2] E. A. Wülfing, 'Ueber einen Apparat zur Herstellung von Krystallschliffen in orientirter Lage.' Zeits. Kryst. Min., 1890, vol. xvii, pp. 445–459.

leg of the tripod was formed by a fixed screw, and the crystal was mounted on a sliding cylinder on the centre of the tripod. This cylinder could not be rotated about its own axis. The use of this apparatus involved rather complicated calculations, and it was on this account that Wülfing abandoned it in 1901.

The apparatus now to be described originated in a small instrument for cutting parallel plates and low angle prisms, devised by one of us working with Professor O. T. Jones several years ago. When we came to improve on this instrument we were able to borrow many useful ideas of construction from Wülfing's apparatus, and we have used a series of holders cut at various angles, similar to those used in both of Wülfing's instruments. From the following description it will be seen that we have entirely altered the method of adjusting the crystal, and have endeavoured thereby to simplify the calculations involved, and have described a possible means of replacing them by graphical solutions.

Description.—The body of the apparatus[1] consists of a triangular brass plate B (fig. 1) surmounted by a brass cylinder D, which is graduated on its upper surface into divisions representing 5°. This outer cylinder carries inside it another brass tube d, which is capable of rotation about a vertical axis; a clamp C enables it to be fixed in any position. The centre of the instrument is occupied by a solid gun-metal plunger P, capable of independent vertical movement only, and restrained from rotation by a pin p, which fits into a slot cut in the rotating tube d. The bed-plate B of the instrument is traversed vertically by three screws S, S_1, S_2, of $\frac{1}{2}$ mm. pitch, which are placed at the apices of an equilateral triangle of which the axis of the instrument is the centre. They are rounded at their lower ends, are made of hardened steel, and are fitted with nuts W which will screw up and clamp them in any desired position. The screw S is provided with a head graduated into six divisions, and reads against the index-finger I. The pitch of the screw S and the distance between its axis and the line joining the screws S_1, S_2 have been so adjusted that one complete revolution of the screw S will give the instrument a tilt of $\frac{1}{2}$° about the line $S_1 S_2$. The graduated head, therefore, reads to 5′ of arc.

The lower end of the plunger P is drilled for the reception of a series of chucks K, on which the crystals are mounted preparatory to being cut. These chucks have been bevelled at various angles ranging at intervals of 10° from 0° to 90°, but in all cases a small surface which is

[1] The instrument has been constructed by Messrs. James Swift & Son, Ltd., 81 Tottenham Court Road, London, W.

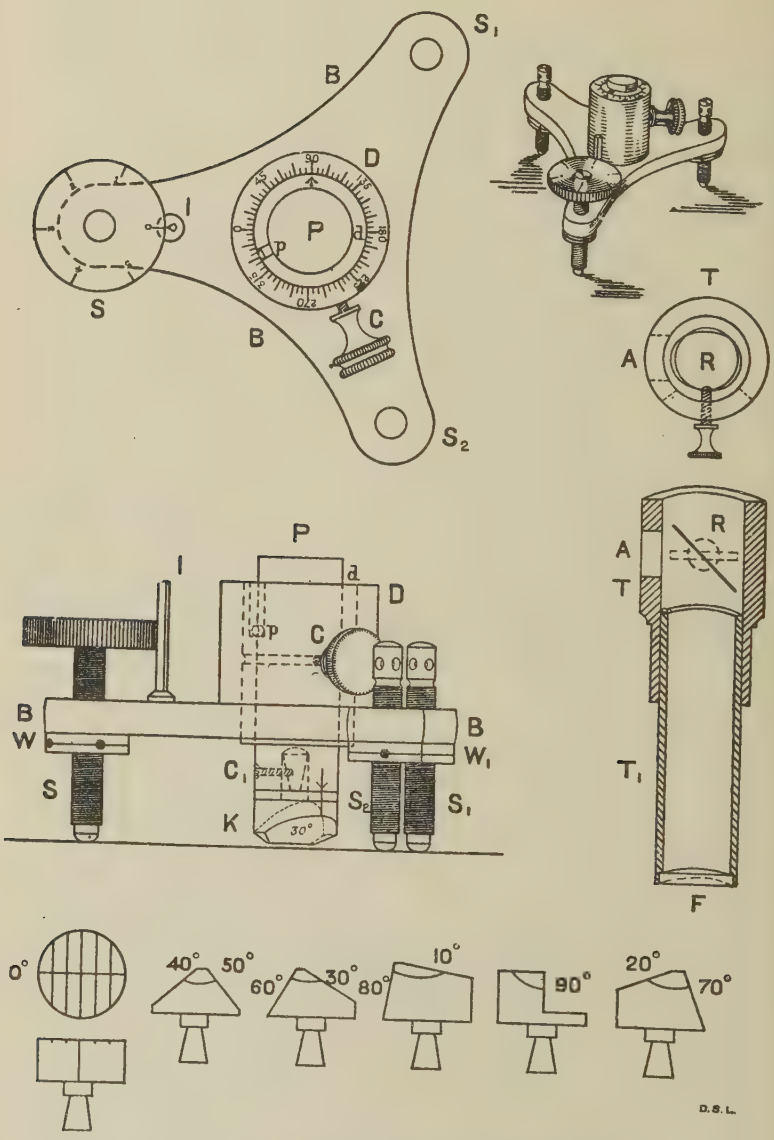


Fig. 1.—Apparatus for cutting crystal-plates and prisms.

normal to the axis of the instrument has been retained, giving a narrow plane between the cut surfaces. Each chuck has an engraved line on its side which can be brought into coincidence with an index engraved on the side of the plunger, and there clamped by the screw C_1. The ends of the chucks are conical, so that, as the screw C_1 works on an inclined surface, the chuck is drawn up into the plunger, and a good contact between the chuck and the plunger is thus insured. The zero chuck has its face engraved with a series of parallel lines crossed centrally by a single line at right angles. When the index on the cylinder d stands at 0°, and the lines on the sides of the chucks are coincident with the index on the plunger, the parallel lines on the zero chuck, and the straight edges of the inclined chucks, are parallel to the line joining S_1, S_2.

By the elevation or depression of the screw S, and the consequent tilting of the instrument, the angular value of any of the chucks may be increased or diminished, and thus any intermediate value may be reached.

The principle underlying the application of the instrument is that a crystal mounted on any of the holders may be rotated in two directions at right angles to each other, one of the axes of rotation being that of the plunger P. By means of these two movements it is possible to bring any desired direction in a suitably mounted crystal normal to the grinding surface.

To set the axis of the instrument normal to the grinding surface.—It will at once be seen that in order to cut a plane on a crystal in any definite direction it is necessary to commence operations with the instrument in some position of reference, which may be termed its zero position. This position is attained when the graduated circle around the plunger stands at 0°, bringing the lines and straight edges of the chucks parallel to the line S_1, S_2, and when the vertical axis of the instrument is normal to the grinding surface.

To fulfil the last condition, the usual method employed is that of standing the instrument on an accurately levelled surface, placing a spirit-level on the instrument and turning the screws S, S_1, S_2 until horizontality is obtained. This method, however, is open to serious objections; the small size of the spirit-level used on the instrument does not conduce to accuracy, and it was found, on trial, that some better method must be sought. We have devised a method which renders the apparatus independent of levels, and at the same time is capable of making adjustments of far greater accuracy.

The instrument is placed on a blackened glass plate. The plunger F is lifted out, and its place is taken by a tube T_1 of the same diameter which carries a plate of optically flat glass F at its lower end, set normal to the axis of the tube. The tube is pushed down the instrument until the optical flat is close to the glass plate on which the instrument is standing. The upper end of the tube carries a vertical illuminator T_2 of the usual pattern, fitted with an inclined cover-glass R.

If light from a signal at a moderate distance away (say 5 feet) is allowed to fall on the cover-glass R, and is reflected down the tube T_1 the observer looking down the tube will see two images of the signal; one reflected from the surface of the optical flat and the other from the glass plate on which the instrument is standing. By turning the screws S, S_1, S_2 these images may be brought into coincidence, and it is then obvious that the axis of the instrument is normal to the surface on which the ends of the screws are resting. The proximity of the optical flat to the glass plate does away with parallax, for the light forming the two images travels practically the same length of path in each case. This method is sensitive to 2′ of arc.

To cut and polish a plane surface.—The crystal is mounted on a chuck by means of a thin film of Canada balsam, or of some other convenient medium, and the chuck placed in position in the plunger. In the case of easily cleavable substances it is sometimes found advisable to cover the crystal after mounting with plaster of Paris, to protect the edges while grinding. The instrument is placed on a sheet of plate glass, a small quantity of flour emery[1] or finest carborundum is introduced beneath the crystal and moistened with a little water. A drop of oil is placed beneath the end of each screw to ensure smooth running. The instrument is held in the hand and moved about on the grinding-plate so that the crystal describes a small circle within the patches of oil in which the screw-legs move. The weight of the plunger is sufficient to keep the crystal in contact with the grinding surface. If carborundum is used, the plane should receive a further grinding on fine emery before it is polished. When a sufficiently large face has been ground, the crystal is cleaned from abrasive material, the screws are wiped free from oil, and the instrument is transferred to a plate of pitch spread with finest washed rouge and water, and moved about as before. A brilliant polish may be obtained by this means on most crystalline substances.

The pitch plate is prepared by pouring well-boiled and strained

[1] Fine emery, taking at least twenty minutes to settle in water.

'British pitch', which can be bought by the pound, inside a brass hoop, 10 inches in diameter, and $\frac{3}{4}$ inch high, which rests on a plane iron plate. The iron plate should not be polished; it should be warm to the hand, and moistened with glycerine to prevent the pitch adhering. When cold, the pitch, with its enclosing ring, may be slid, not lifted, off the iron plate; it will be found to have an excellent lower surface.

Mr. Swift informs us that for some substances, especially calcite, a brilliant polish may be produced by the finest washed putty-powder spread on satin tightly stretched over a plane iron plate.

As in this instrument we are only cutting and polishing a small central portion of a relatively large area represented by the triangle $S\ S_1\ S_2$, the planes so cut and polished are exceptionally flat, and take a polish to their extreme edges.

To cut a face parallel to a given face.—The instrument being set in its zero position, the crystal is mounted on the given face on the zero holder. It is then ground to a suitable thickness, and polished in the manner described above. Faces so cut are accurately plane and vary very little from true parallelism. The only error introduced is that entailed in setting the given face on the holder, which can be reduced to a minimum by using the thinnest possible film of mounting medium.

To cut a plane O, in a zone of which the axis is represented by an edge $[r_1 r_2]$.—With the instrument in its zero position, the crystal is mounted on a face parallel to one of the faces of reference, r_1, on the chuck whose angle, ϕ, most nearly approximates to the angle $O \wedge r_1$, with the edge $[r_1\ r_2]$ parallel to the straight edge of the chuck. The difference, δ, between the angle $O \wedge r_1$ and ϕ is corrected for by rotating the screw S in the required direction, and a small face O_1 is ground and polished. The cutting and polishing of this small face need take only a few minutes. The crystal on its holder is then transferred to a goniometer, and the position of O_1 is accurately determined.

Two errors may have been introduced; one in setting the face r_1 parallel to the face of the chuck; the other in setting the edge $[r_1 r_2]$ parallel to the straight edge of the chuck, i.e. to the line $S_1\ S_2$ joining the two fixed screws. To determine these errors the measurements made on the goniometer are transferred to a stereogram by the following method:

Let C, the centre of the projection (fig. 2), represent the pole of the axis of the instrument, P the pole of the normal to the face of the chuck, where $CP = \phi$, the angle of the chuck. Then, when the instrument is in its zero position, C is also the pole of the grinding surface and the

screw S lies in the plane CPS. Let δ be the tilt given to the instrument by the screw S, then the pole of the grinding surface, and therefore of the face ground, will move to O_1, where $C \wedge O_1 = \delta$. The position of O_1 is therefore fixed with respect to C and P.

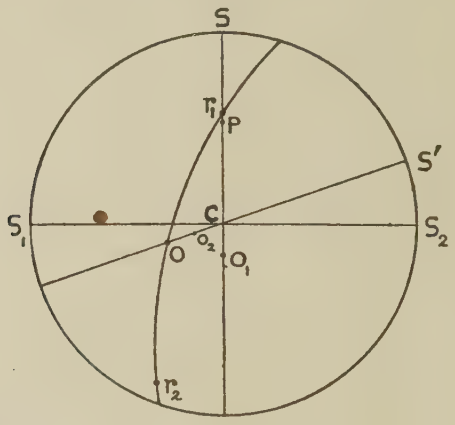


Fig. 2.

Let $O_1 r_1$ be the angle measured on the goniometer between these two faces. If the setting of the face r_1 parallel to the face of the chuck has been effected accurately, the angle $O_1 r_1 = \phi + \delta$, and the point r_1 will coincide with P. In any case, the difference should be almost negligible and the pole r_1 may be plotted on the zone CPS at a distance $O_1 r_1$ from O_1.

By drawing small circles from O_1 and r_1 with radii of angles $O_1 r_2$ and $r_1 r_2$ as measured on the goniometer, the position of r_2 can be determined. If the edge $[r_1\ r_2]$ has been set accurately parallel to the line $S_1 S_2$ the face r_2 will lie in the zone CPS, but as this setting is only done by eye the face r_2 may be found to lie off this zone, as indicated on the stereogram. For the sake of clearness the errors have been exaggerated in the figure. Having fixed the positions of r_1 and r_2 with respect to the instrument, the position of the required face O can be determined. It lies on the zone $[r_1\ r_2]$ at an angle Or_1 with r_1.

It is now required to bring the pole of the grinding-lap from O_1 to O. This is accomplished by turning the plunger through an angle equal to the angle SCS', the effect of which is to bring the screw S and the pole of the grinding-lap into the plane CO. The pole of the grinding-lap is

now at O_2, where $CO_2 = CO_1$. By applying a correction in the tilt represented by the angle $CO - CO_2$ the pole of the grinding-lap is moved to O, and the desired face O is then ground and polished.

The poles r_2 and O are usually so close to the zone r_1CO_1 that the necessary corrections cannot be determined graphically on a stereographic projection; they can, however, be computed by solving the spherical triangles $r_1r_2O_1$ and r_1OC whereby the angles r_1CO and CO can be found.

General Case: To cut a plane on a crystal in any desired direction.— Certain prominent faces of the crystal are chosen as planes of reference, and the position of the required plane with respect to these faces is

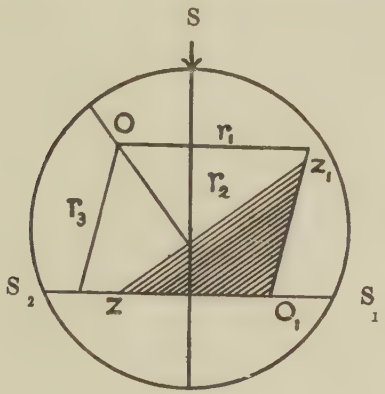


FIG. 3.

determined. Two faces of reference are sufficient, but the presence of a third face to which measurements can be made acts as a useful check on the calculations. Let O be the plane required, r_1 and r_2 being the planes of reference (fig. 3).

If neither of the zones Or_1 or Or_2 is represented by an edge on the crystal, it is mounted on the zero chuck with one face, say r_2, parallel to the face of the chuck and the edge $[r_1r_2]$ parallel to the lines engraved on it. The plunger is then rotated about its axis through the angle between the zones $[r_1r_2]$ and $[r_2O]$, so that the zone-axis $[r_2O]$ comes into parallelism with the line S_1S_2 joining the two fixed screws. A suitable tilt is now given to the instrument by means of the screw S and a small face is ground. This at once gives an edge ZZ_1 parallel to the zone-axis $[r_2O]$. The crystal is then removed from the zero chuck, and is mounted on the same face r_2 on a chuck whose angle most nearly approximates to $r_2 \wedge O$, with the edge ZZ_1 parallel to the

straight edge of the chuck. The requisite correction is applied by turning the screw S, and the face O is cut by the method given above.

An example which serves to illustrate this general case is the cutting of a plate normal to the optic axis from a small cleavage rhombohedron of calcite.

The rhombohedron is cemented with a thin film of Canada balsam on to the zero chuck with one of its edges $[r_1r_2]$, parallel to the lines engraved on the chuck, and therefore parallel with the line S_1S_2. The plunger P is now turned through half the angle between the zones $[r_2r_3]$ and $[r_1r_2]$, namely 39° 3′. The graduated screw S is turned through 20 complete revolutions (= 10°). Grinding now gives a face at an angle of 10° with r_2 and in the zone Or_2 [111, 100]. This face need not be polished. The instrument is now brought back to its zero position. The crystal is removed from the zero chuck and cemented on the 40° chuck with r_2 parallel to its face, and the edge of reference just obtained parallel to the straight edge of the chuck. As $r_2 \wedge O$ in calcite is 44° 36′ it is necessary to add a tilt of 4° 36′ by means of the graduated screw S. Grinding will now give a face approximately parallel to O. The crystal, still on the chuck, is measured on the goniometer, and the poles are projected on a stereographic projection.

Here an additional error may have been introduced owing to the re-setting of the crystal on the 40° chuck, but with careful manipulation the face ground should not be more than 2° from the required position. The corrections may be computed by a modification of the method described in the preceding case, but where the errors are small the following graphical method commends itself for its simplicity and sufficient accuracy.

The crystal is removed from the inclined chuck, and re-cemented on the ground face on the zero chuck with the edge ZZ_1 (fig. 3) parallel to the lines engraved on the chuck, and a small parallel face is ground and polished. The angles made by this face O_1 with the faces of the rhombohedron are measured on the goniometer.

Let the calculated angles between the face required, O, and the faces of reference be: $O \wedge r_1 = \theta_1$, $O \wedge r_2 = \theta_2$, $O \wedge r_3 = \theta_3$; and let the angles measured from O_1 be: $O_1 \wedge r_1 = \theta_1 \pm d_1$, $O_1 \wedge r_2 = \theta_2 \pm d_2$, $O_1 \wedge r_3 = \theta_3 \pm d_3$, where d_1, d_2, and d_3 represent the differences between the observed and calculated angles. These angles are plotted on a greatly magnified stereographic projection of which only the central portion, represented by a small circle of 2° radius, is utilized.

Let O_1, the centre of projection (fig. 4), be the pole of the face which

has been cut and of the axis of the instrument. The poles of the faces of reference, r_1, r_2, and r_3, lie at great distances away in the directions O_1r_1, O_1r_2, and O_1r_3, and these lines represent great circles passing through the poles of the faces of reference and of the face cut. As the distance from O to O_1 is very small—less than 2°—the angles r_1Or_2 and $r_1O_1r_2$ may be taken as equal. Small angles near the centre of this enlarged projection may be expressed as linear ratios, and small circles drawn round the poles of the planes of reference and passing near the centre of the projection may be drawn as straight lines.

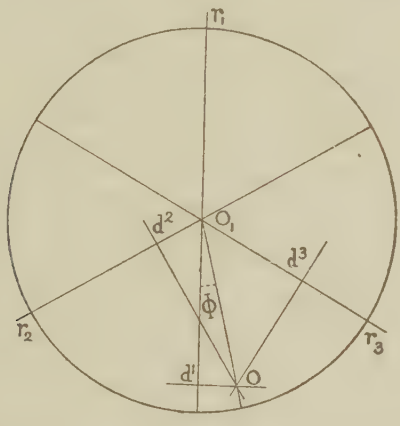


FIG. 4.—The radius of the circle represents 2°, the measured angles O_1r_1, O_1r_2, and O_1r_3 are 42° 54′, 45° 6′, 45° 48′, and the values of d_1, d_2, d_3 are −1° 42′, +0° 30′, +1° 12′.

With O_1 as centre, describe a circle of which the radius represents some convenient angle, say 2°, slightly greater than the largest error found in the measured angles. In the directions of r_1, r_2, and r_3, lay off distances proportional to d_1, d_2, and d_3, negative values of d_1, d_2, and d_3 being measured away from the poles of reference. Through the points so obtained draw lines perpendicular to the lines O_1r_1, O_1r_2, O_1r_3. These lines will be found to meet in a point O, which represents the pole of the face required.

It will be seen that a rotation of the crystal in the plane of projection through an angle Φ, and a tilt measured by OO_1 given by the screw S, in a plane at right angles to the plane of projection will bring the pole of the grinding surface from O_1 to O.

In an actual experiment on a cleavage rhombohedron of calcite, the application of corrections by this method gave a face for which the maximum difference between the measured and calculated angles amounted to 9 minutes.

The description of this graphical method has been given in some detail, as it illustrates a case that may frequently arise where the face required does not lie in a zone between two given faces. The cutting of certain faces in different crystals requires special treatment in each case. The method of computing the necessary corrections from the stereographic projection as outlined for the case of a face in a zone between two given faces is always applicable, but it must be left to the ingenuity of the individual to take full advantage of the habit of each crystal and to devise simple methods for the solution of each problem.

The instrument has been very carefully constructed, and the angular values given by the inclined chucks and by the rotation of the screw *S* are sufficiently accurate for most purposes. The angles given by the screw *S* may show errors of 10 minutes in an angle of 5°. For accurate work this screw can be calibrated by setting a plate of soft glass on the zero chuck, cutting a parallel face, and then cutting a series of small faces for successive rotations of the screw head. In cutting parallel plates the difference from parallelism may amount to 3 minutes, but here the error depends on the setting of the plate on the chuck; by using the thinnest possible film of mounting medium, this error may be made practically negligible. As mentioned above, the errors introduced in preparing a plate of calcite normal to the optic axis showed a maximum value of 9 minutes, so that the degree of accuracy obtained seems to be sufficient for most optical work on minerals.

Those who have occasion to use this apparatus will doubtless encounter many difficulties and some disappointments. Patience, cleanliness, and some skill in manipulation are requisite for the preparation of accurately orientated plates and prisms, but, when the working of the instrument is understood, the results obtained with it seem to amply justify the somewhat lengthy computations and corrections involved.

Optically uniaxial Augite from Mull.

By A. F. Hallimond, B.A., F.G.S.
Assistant Curator, Museum of Practical Geology, London.
With an analysis by E. G. Radley.

[Read January 27, 1914.]

THE mineral here described was recently collected by the officers of the Geological Survey during their work for the six-inch map of the Island of Mull. It is present as minute phenocrysts in a dark, glassy, magnetite-bearing rock,[1] which is intruded as sheets in the Tertiary lavas nearly one mile south-south-west of Pennygael.

The small rounded crystals of augite are seldom more than $\frac{1}{2}$ mm. in diameter and are traversed by irregular cracks. They contain a few negative crystals, and are occasionally darkened, probably with included magnetite. They appear to have been reabsorbed to some extent by the matrix.

For the purpose of separating the mineral, the rock was reduced to a moderately fine powder and immersed in Thoulet's solution. The augite fell with about an equal amount of magnetite and a few flakes of mica. The mica particles were lost during the washings, and the magnetite was then picked out with a magnet, leaving augite with a certain number of pieces of the base weighted with augite. This residue was boiled with dilute nitric acid and separated by methylene iodide, in which the augite sank readily. The mineral thus obtained was washed with benzene and taken for analysis; it was quite free from other heavy minerals.

A number of the larger grains were embedded in Woodwardian cement and ground to a thick section. In this it could be seen that the optical properties are extremely uniform, the extinction being the same through-

[1] An analysis of the rock has been given in the Summary of Progress of the Geological Survey of Great Britain for 1912, 1913, p. 69 (Slice No. 15990).

out each grain, and no sign of zonal structure was observed. In grains of low birefringence could be seen an almost uniaxial interference-figure, which showed little or no resolution into hyperbolae. The birefringence was measured by means of the micrometer focusing-screw, and the mean value 0·028 was obtained on sections which showed the highest tint in the centre of the interference-figure.

The refractive index could not be determined directly on account of the smallness of the grains. Mixtures of methylene iodide and monoiodobenzol were therefore made, having indices respectively equal to those of the ordinary and extraordinary rays in the augite. These, when adjusted with small pieces of the mineral, and illuminated by a narrow beam from the monochromatic apparatus, showed the Becke line moving in one direction for red light and in the opposite for green. A fairly accurate value was so obtained for the ordinary ray (the mixture here being almost pure methylene iodide); that for the extraordinary was possibly slightly low, since the maximum value had to be taken. The refractive indices of the liquids were then measured on the Hutchinson universal apparatus, and the values obtained for sodium-light at room-temperature were—

$$\omega = 1{\cdot}714,\ \epsilon = 1{\cdot}744;\ \epsilon - \omega = 0{\cdot}030.$$

The mineral is markedly pleochroic:

ordinary ray, smoky-brown; extraordinary ray, pale-yellow.

The cleavage is rather difficult, and no measurement of the cleavage angle could be obtained. In the crushed fragments it could be seen that there are two cleavage directions approximately at right angles, but it was impossible to get a reliable value for the extinction on the cleavage surfaces. A large number of readings were therefore taken and a statistical curve plotted, having the extinction values as abscissae and the numbers of readings at each value as ordinates. The curve showed a well-defined maximum at 30°, though there were numerous readings from 26° to 41°. Very few readings of 45° were obtained. If the lath-shaped pieces are supposed to be tilted in the prism-zone by adhering fragments, equal numbers of readings should occur on either side of the correct value. In the present case the most frequent reading was 30°; and of the total number of 324 readings, 163 fell between 0° and 30°, and 161 between 31° and 45°. The most probable value for the extinction-angle on the cleavage seems, therefore, to be $30\frac{1}{2}°$. The sign of the elongation is almost uniformly positive, and assuming the prism angle mm' to be 90°, the angle $c\dot{c}$ is calculated as approximately 40°.

No measurements of the crystal forms could be obtained, but it seems most probable that the optic axis here occupies a position similar to that of the acute bisectrix in the biaxial pyroxenes.

The following analysis of the separated mineral has been made by Mr. E. G. Radley in the Survey Laboratory :—

SiO_2	49·72	0·82318	0·83379 (acids)
TiO_2	0·85	0·01061	
Al_2O_3	0·90	0·00881	
Fe_2O_3	1·72	0·01075	
FeO	27·77	0·38569	
MnO	0·98	0·01381	
(Co,Ni)O	nil	—	
CaO	3·80	0·06786	0·87686 (bases)[1]
MgO	12·69	0·31442	
K_2O	0·12	0·00127	
Na_2O	0·23	0·00370	
Li_2O	trace	—	
H_2O at 105° C.	0·08	—	
H_2O above 105° C.	1·27	0·07055	
	100·13		

Specific gravity at 17° C., 3·44.

The mineral is sharply distinguished from the usual type of diopside by its low content of lime. The alumina is also low, the composition approximating to the pure metasilicate ratio 1 : 1. In fact, the composition is almost that of a hypersthene, and the analysis is quite within the limits of the hypersthenes quoted by Hintze. The mineral agrees generally in physical properties and in composition with the pyroxenes of low axial angle discussed by Wahl,[2] as far as data for these exist. It may be remarked that the rock in which this augite occurs is considerably more acid than the diabases of the series chiefly dealt with in Wahl's paper. This mineral would appear to differ also, in several essential details, from the 'pigeonite' of Winchell, notably in the specific gravity, birefringence, extinction-angle, and lime and titanium content. The two minerals agree in having a low axial angle, but in other respects they must be regarded as distinct.

[1] Sum of molecular ratio of bases, neglecting $(Al, Fe)_2O_3$, 0.85730.

[2] W. Wahl, Min. Petr. Mitt., 1907, vol. xxvi, pp. 1–131. A somewhat similar mineral was described by A. N. Winchell, Amer. Geol., 1900, vol. xxvi, p. 199, under the name of pigeonite. Cf. Lacroix, Min. de la France, 1910, vol. iv, p. 767.

Augite from Bail Hill, Dumfriesshire.

By Alexander Scott, M.A., B.Sc.

Carnegie Research Scholar of the University of Glasgow.

[Read March 17, 1914.]

THE crystals to which this paper refers are found at Bail Hill, about three miles north of Sanquhar, in Dumfriesshire. At this locality volcanic rocks of Arenig age outcrop in the midst of the greywacke of the Southern Uplands. The rocks are mainly lavas, and include some coarse-grained tuffs which are composed chiefly of augite- and hornblende-andesites. In the andesitic fragments, there are numerous porphyritic crystals of a black augite, which can be easily separated from the rest of the rock. Isolated crystals of augite and hornblende occur also in the matrix of the tuffs. No mention of this occurrence is made in Heddle's 'Mineralogy of Scotland', and apparently the only reference to it in previous literature is the short petrographic description in the Geological Survey Memoir.[1] There, Teall mentions the occurrence of sharp crystals of augite showing the common forms (100), (010), (110), ($\bar{1}$11). The mineral is described as yellow to yellowish-green in colour, slightly pleochroic, and containing some inclusions of magnetite.

The crystals are black in colour, fairly opaque, and have the usual well-developed cleavage parallel to the prism-faces. The forms observed are few in number, comprising only the four mentioned above, namely, *a* (100), *b* (010), *m* (110), and *s* ($\bar{1}$11), while there is nothing unusual in the developments of these forms in the two types which are commonly found. The first type consists of untwinned crystals with an approximately equal development in the three axial directions, and varying in size up to 1·5 centimetres in diameter. The faces in the prism-zone have a bright lustre, but the pyramid-faces are usually dull. With the exception of some very small crystals, most of the specimens of this kind show a curious deformation. The *b*- and *m*-faces are perfectly plane,

[1] 'Silurian Rocks of Scotland,' Mem. Geol. Survey, 1899, pp. 87, 306.

but the *a*-faces are convex in the plane parallel to *b* (010), the degree of convexity being a maximum near the 'acute angle'[1] of the crystal, and a minimum at the 'obtuse angle'. The face, of course, tends to broaden out as it curves inwards, and on the whole somewhat resembles a portion of a parabolic cylinder, having as its axis the *b*-axis of the crystal. The *s*-faces are correspondingly concave, as are also the *s*-*s* edges, which are often replaced by a curved surface at the 'acute' contact with the *a*-face, especially in those crystals which are highly distorted.

The second type is composed of crystals elongated parallel to the prism-faces, and invariably twinned on *a* (100). As before, the faces in the prism-zone are bright and the *s*-faces 'matte', but in this case the distortion is either very slight or absent. In both types intergrowths both of twinned and untwinned crystals are very common, and occasionally as many as twelve crystals are found thus intergrown. The individuals of these groups are arranged sometimes in a roughly stellate fashion (as figured by Rosenbusch[2]), and sometimes with the respective prisms more or less parallel. In one example, the upper half is a twin of the type described above, while the lower half is untwinned and composed of a single crystal, but the habit is different from the crystals of this kind described by Williams from Orange County, New York.[3]

It was found impossible to measure the larger crystals accurately, on account of the curvature of the faces, but a number of small crystals, up to 1·5 mm. in diameter, gave consistent readings, though the faces were so dull that a film of silver had to be chemically deposited on them in order to obtain good reflections. Five crystals were measured, and the results are given below.

	Calculated.	Observed.	No.	Limits.
am = (100) : (110)	46° 30′	46° 28′	12	46° 21′–46° 38′
bm = (010) : (110)	*	43 30	12	43 17 –43 42
ab = (100) : (010)	90 0	89 58	1	— —
mm = (110) : ($\bar{1}$10)	87 0	—	—	— —
sm = ($\bar{1}$11) : ($\bar{1}$10)	*	59 7	4	58 48 –59 26
ms = (110) : ($\bar{1}$11)	78 41	78 52	2	78 38 –79 6
bs = (010) : ($\bar{1}$11)	*	60 36	5	60 25 –60 46
ss = ($\bar{1}$11) : ($\bar{1}\bar{1}$1)	58 48	58 41	2	58 34 –58 48

The axial ratios are:—

$$a : b : c = 1{\cdot}0932 : 1 : 0{\cdot}5844; \ \beta = 74° 12′.$$

[1] i. e. the acute angle between *a* and the *s*-*s* edge.

[2] H. Rosenbusch, Mikroskopische Physiographie, 1905, vol. i (2), p. 207, Pl. VI, fig. 3.

[3] G. H. Williams, Amer. Journ. Sci., 1887, ser. 3, vol. xxxiv, p. 275.

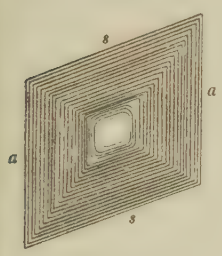
In thin section, the augite is yellowish-green in colour (in sections 0·04 mm. thick) with slight pleochroism, the absorption for a and c being the same, while that for b is slightly greater. In a section of a thickness of 0·5 mm., the difference in absorption is very marked, the colours being a and c yellow-green, b deep red-brown.

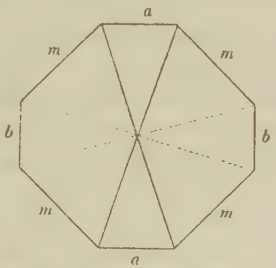
A section in the symmetry-plane shows the hour-glass structure so characteristic of augites containing titanium. In general there are four sectors, each triangular in shape and having a common point in the centre of the crystal. Two of these have the trace of the *a*-face as their external boundary, and the other two the *s*-*s* edge or the trace of an *s*-face. Sometimes the sectors do not meet in the centre, which is then occupied by a non-sectored core approximately rhomb-shaped, as shown in fig. 1. A section through the centre of the crystal and perpendicular to the prism-faces shows eight sectors, two bounded by the *a*-faces and lines joining the *a*-*m* angles to the centre, two by the *b*-faces and corresponding lines, and the remaining four by the *m*-faces and lines to the centre. The divisions separating the *a*-sectors from the others are generally well-defined, but those separating the *b*- and *m*-sectors are often indefinite, and can only be recognized in very thick sections. Fig. 2 shows the arrangement in such a section. Sections parallel to *a* (100) show different arrangements according as they are through the centre of the crystal, or between there and the *a*-face. In the former, four sectors are seen, two bounded externally by the *b*-faces, and the other two each by two contiguous *s*-faces. In the latter the trace of an *a*-sector appears in the middle, the size varying with the distance from the centre. It is six-sided, the sides being parallel to, and in the same ratio (in size) as, the boundaries of the *a*-face. The remainder of the section is occupied by the *s*- and *m*-sectors (as in fig. 3), unless the section is near the centre of the crystal, when part of the *b*-sectors appear in addition.

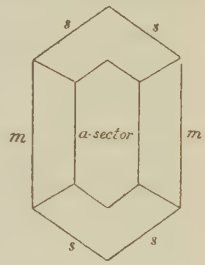
Considering now the distribution of the various sectors in three dimensions, it is obvious that the *a*-sectors each consist of a pyramid with a hexagonal base, the *a*-face; the *b*-sectors each of a pyramid with a rectangular base, the *b*-face; the *m*-sectors each a pyramid with a trapezohedral base, the *m*-face; while the two *s*-sectors occupy the remainder of the crystal. In none of the sections could any indication be obtained that each of the *s*-sectors was divided into two, one for each face. If they were so divided the optical properties of both parts were apparently the same. The optical properties of the *a*- and *s*-sectors were determined, but not those of the others. It is most probable that

the *b*- and *m*-sectors resemble closely the *s*-sectors, as in some of the sections cut, these three sectors could not be distinguished optically from each other.

The various sectors are not homogeneous in themselves, but show a number of parallel bands resembling multiple-twinning. This is only occasionally visible in ordinary light, but it can generally be seen when the section is between crossed nicols, through a few degrees on each side of the extinction position. The bands in each case are parallel to the base of the pyramid which composes the particular sector, but are not







Sections of Augite crystals.

FIG. 1.—Parallel to *b* (010), through centre of 'cored' crystal and showing 'periodic' banding.

FIG. 2.—Perpendicular to prism-zone, through centre of non-cored crystal.

FIG. 3.—Parallel to *a* (100), through *m*-faces.

equally distinct in all the sectors, being more pronounced in the *a*- and *s*-sectors than in the *b*-sectors, while they are often difficult to detect in the *m*-divisions. The extinction varies continuously from one band to the next (like the 'shadowy' extinction of strained plagioclase) and the maximum variation in any one sector is less than 3°. Where a central core exists it is not, in general, homogeneous, but shows a pronounced zonal structure, the extinction varying as in the sectors.

This structure bears a close resemblance to those obtained by 'periodic crystallization', such as Liesegang's phenomenon.[1] There seems to be the same alternate deposition of two layers differing in composition, though in the one case the layers are spherical, in the other, plane. It is difficult to see any reason for this periodicity, as there is no evidence to show that titanaugites crystallize from more viscous solutions (magmas) than any other pyroxene, nor, so far as is known, is there any greater tendency for supersaturation to occur.[2]

[1] R. E. Liesegang, 'Ueber die Schichtungen bei Diffusionen,' Leipzig, 1907.

[2] The most generally accepted explanation of Liesegang's phenomenon is that

This hour-glass structure is common to most of the augites which contain titanium oxide, and it was first described by Werveke.[1] The explanation first given by Rosenbusch[2] was that the crystals developed in such a manner that a section in the *b*-plane showed a kind of bifurcated structure and that the pyramids at the *a*-faces were filled up later. On the other hand, many mineralogists maintain that the various sectors all grow more or less at the same rate, just as any ordinary crystal. In the present case the latter is the most plausible, as some of the bands seem to pass from one sector to the next. The crystals probably developed by the addition of successive series of layers, the latter varying somewhat in composition, and the deposition of the layers taking place more or less uniformly on all the faces of the crystals.

With regard to the different sectors, the difference in optical properties (see below) would argue a difference in chemical composition. Since the structure is apparently confined to pyroxenes containing a fair amount of titanium oxide,[3] it is reasonable to assume that the titanium content varies in the different sectors. But whether it is the amount of titanium alone that varies or that of some complex molecule containing titanium, must remain a matter of conjecture, as nothing is known, at present, about the condition of the titanium in these pyroxenes. In connexion with this structure, some results of Gaubert's work may be significant. He found[4] that the habit of crystals of hydrated phthalic acid was greatly modified by the presence of substances, such as dyes, in the solution, and further, that such crystals, growing from a solution containing methylene blue, were coloured blue and showed an hour-glass structure, the pyramids with (011) as their base being more intensely coloured than those with (210) or (212) as base. Crystals of meconic acid[5] show a more pronounced difference between the colour of the various sectors, the prism (110) being the base of the most intensely coloured sector. (Meconic acid crystallizes in the orthorhombic system.) A curious coincidence is that these crystals showed a much greater

due to Ostwald (Zeits. Physik. Chem., 1897, vol. xxiii, p. 365), who attributes it to supersaturation.

[1] L. van Werveke, Neues Jahrb. Min., 1879, pp. 482, 882.

[2] H. Rosenbusch, Mikroskopische Physiographie, 1905, vol. i (2), p. 210.

[3] J. Blumrich (Min. Petr. Mitt., 1892, vol. xiii, p. 239) was the first to notice that this hour-glass structure is practically confined to augites in alkali-rich rocks. A summary of the different occurrences is given by Pelikan (Min. Petr. Mitt., 1896, vol. xvi, pp. 1–64).

[4] P. Gaubert, Bull. Soc. franç. Min., 1905, vol. xxviii, p. 286.

[5] P. Gaubert, Compt. Rend. Acad. Sci. Paris, 1910, vol. cli, p. 1134.

tendency to develop curved faces than those prepared from pure solution. It seems feasible, as indeed Gaubert has suggested,[1] that the structure of titanaugites arises in some similar way and, as has been indicated above, the development of the hour-glass structure seems to be connected with the presence of titanium. Complete analyses of the various sectors would probably assist much in the explanation of this phenomenon, but so far this has not been found possible.

The *extinction-angles* given below are the means for the respective sectors and were measured from the trace of the twinning-plane in a section of a twin-crystal cut parallel to b. The plane of the optic axes is the symmetry-plane, and $\mathfrak{b} = b$. The values of $\mathfrak{c} : \dot{c}$ were determined for thallium-, sodium-, and lithium-light, a Hilger monochromatic illuminator being used for the production of the light. (This was used for all the optical properties.)

	λ.		a-sector.	s-sector.
Li-light	6710	$\mathfrak{c} : \dot{c} =$	47° 48′	45° 2′
Na-light	5890	„ =	48 32	45 42
Tl-light	5350	„ =	49 19	46 19

Refractive Indices.—For the determination of the refractive indices, six prisms were prepared, all with a refracting angle of about 40°. With any higher angle the minimum deviation could not be found exactly, owing to the strong absorption. Two of the prisms were cut so that each gave α and γ for the a-sector, while other two, from the same crystal, gave α and γ for the s-sector. One of the remaining two gave β and an index near γ for the a-sector, and the other the corresponding values for the s-sector. The values obtained for thallium- and sodium-light are given below:—

	α.	β.	γ.	
a-sector	1·708	1·713	1·732	Na-light.
	1·708		1·732	
	1·713	1·718	1·737	Tl-light.
s-sector	1·697	1·702	1·722	Na-light.
	1·696		1·721	
	1·703	1·708	1·727	Tl-light.
	1·702		1·727	

Consistent values were obtained, the variations from the mean being always less than 0·001 for any one prism.

[1] P. Gaubert, 'Recherches récentes sur le Facies des Cristaux,' 1911, p. 26.

The mean values of the double-refraction are:—

	$\gamma-\alpha$.	$\gamma-\beta$.	$\beta-\alpha$.	
a-sector	0·024	0·019	0·005	Na-light.
	0·024	0·019	0·005	Tl-light.
s-sector	0·025	0·0195	0·0055	Na-light.
	0·0245	0·019	0·0055	Tl-light.

In order to determine the *optic axial angles*, four sections, two perpendicular to the acute bisectrix and two perpendicular to the obtuse, were prepared, and the apparent acute and obtuse angles measured by immersing the section-plates in α-monobromonaphthalene of refractive index 1·665. The values of β obtained from the prisms were used in calculating the true angles in the results tabulated below:—

	Section.	Sector.	2H(Na).	2H(Tl).	$2V_a$(Na).	$2V_a$(Tl).
Acute angle	1.	a	64° 32′	64° 5′	62° 30′	61° 52′
	2.	a	64 18	63 55	62 18	61 44
	2.	s	63 28	62 53	61 59	61 6
Obtuse angle	3.	a	123 58	123 47	61 52	62 34
	3.	s	123 22	123 20	61 8	61 42
	4.	a	122 28	123 6	63 6	62 54

The average values are:—

a-sector $2V_a(\text{Na}) = 62° 34'$ $\quad 2V_a(\text{Tl}) = 62° 16'$

s-sector $\quad = 61\ 30$ $\quad = 61\ 24$

The values calculated from the mean values of the acute and obtuse angles for the a-sector are:—

$$2V_a(\text{Na}) = 62° 26'$$
$$2V_a(\text{Tl}) = 62\ 2$$

and the values of β are:—

$$\beta(\text{Na}) = 1{\cdot}712 \qquad \beta(\text{Tl}) = 1{\cdot}713,$$

which agree fairly well with the values obtained from the prisms. In the case of the s-sectors the agreement is not so good, the values being:—

$\beta(\text{Na}) = 1{\cdot}708$ $\quad \beta(\text{Tl}) = 1{\cdot}705$[1] as compared with the prism values $\beta(\text{Na}) = 1{\cdot}702$ $\quad \beta(\text{Tl}) = 1{\cdot}708$.

[1] The differences between the values of β for the s-sector as calculated from the axial angle and as observed by the prism method are probably to be explained by the fact that section 3 contained b- and m-sectors in addition to a and s, and it is very difficult to distinguish those sectors from the s. The prism values of β are certainly the more reliable.

The dispersion of the bisectrices is fairly strong, so that a section parallel to b never shows complete extinction between crossed nicols in white light. The axial dispersion is slight and is $\rho > v$.

Chemical Composition.—As it was found impossible to separate the sectors and analyse them individually, a bulk analysis was made of a sample composed of several crystals. Column I in the following table gives the percentage by weight, and column II the molecular percentage, water being neglected in the calculation.

	I.		II.
SiO_2	45·66	... ...	47·71
TiO_2	2·16	... ...	1·76
Al_2O_3...	3·53	... ...	2·13
Fe_2O_3...	8·78	... ...	3·45
FeO	4·16	... ...	3·64
MnO	0·19	... ...	0·12
MgO	9·34	... ...	14·79
CaO	22·17	... ...	24·75
Na_2O	1·50	... ...	1·50
K_2O	0·26	... ...	0·15
H_2O above 110° ...	1·37	....	—
H_2O below 110° ...	0·61	... ...	—
P_2O_5	trace [1]	... ...	—
	99·73		100·00

If the mineral is assumed to consist of the molecules aegirine-acmite —Na (Fe, Al) Si_2O_6,—diopside-hedenbergite—Ca (Mg, Fe, Mn) Si_2O_6,—and Tschermak's hypothetical silicate—Mg $(Al, Fe)_2SiO_6$—the composition by weight is 11·8 per cent. of the first of these, 73·0 per cent. of the second, and 15·2 per cent. of the third.

The determination of the specific gravity of the powdered mineral by a pycnometer method gave a mean value of 3·291.

Numerous attempts have been made to correlate the optical properties of the pyroxenes with their chemical composition, and various rules have been formulated. Tschermak [2] stated that the optical properties varied with the composition, the amount of iron oxides being a potent factor in

[1] Less than 0·006 per cent.

[2] G. Tschermak, Min. Mitt., 1871, p. 21.

the non-aluminous pyroxenes. Wiik[1] found that in the Finnish diopsides the extinction-angle increased in a somewhat irregular fashion with the amount of ferrous oxide, while Doelter[2] formulated the law that the extinction-angle increased with the sum of the ferrous and ferric oxides and alumina, the increase being more regular if the amounts of the different metasilicates were considered in place of the oxides. Thus when the ratio of the iron-bearing metasilicates is less than 1 : 4 the extinction is less than 41°; when the ratio is between 1 : 4 and 1 : 3 the extinction varies from 41° to 45°, and when it is greater than 1 : 3 the extinction is greater than 45°. The extinction also seems to increase with the amount of alumosilicate and ferrisilicate molecule. In the present case the extinction varies from 45° to 49°, and the ratio of calcium-ferrous metasilicate to the other metasilicates is approximately 1 : 4, the amount of Tschermak's silicate being about 15 per cent. While comparison is difficult owing to the non-homogeneity of the Bail Hill crystals, it will be seen that they agree approximately with Doelter's rule.

Most of the values for the refractive indices given by Hintze[3] are lower than those obtained in this instance. The indices would seem to increase with the amount of the hedenbergite molecule. Michel Lévy and Lacroix[4] found refractive indices for two augites from Auvergne which resemble our values fairly closely:—

		α.	β.	γ.
Auvergne ...	...	1·712	1·717	1·733
		1·706	1·712	1·728
Bail Hill ...	...	1·708	1·713	1·732

Tschermak[5] described a mineral from the Bohemian Mittelgebirge with the optical properties:—

$$c : \dot{c}\ 45°\ 30', \beta = 1{\cdot}70, 2V = 61°.$$

(Cf. analysis V in table below).

These minerals, however, were not analysed. Wülfing[6] investigated crystals with a composition similar to those of Bail Hill (Analysis VI in

[1] F. J. Wiik, Zeits. Kryst. Min., 1884, vol. viii, pp. 208-210.
[2] C. Doelter, Neues Jahrb. Min., 1885, vol. i, p. 56.
[3] C. Hintze, 'Handbuch der Mineralogie,' 1897, vol. ii, pp. 1025-1029.
[4] A. M. Lévy and A. Lacroix, 'Les Minéraux des Roches,' 1888, p. 265.
[5] G. Tschermak, Min. Mitt., 1871, p. 29.
[6] E. A. Wülfing, Min. Petr. Mitt., 1896, vol. xv, pp. 29-48.

table given below), and found the following values for the optical constants:—

$\alpha(D) = 1.6975$ $\beta(D) = 1.7039$ $\gamma(D) = 1.7227$ $2V(D) = 61° 22'$
$\alpha(E) = 1.7029$ $\beta(E) = 1.7093$ $\gamma(E) = 1.7284$ $2V(E) = 60\ 45$

which are close to the values found above for the *s*-sector:—

$\alpha(Na) = 1.696$ $\beta(Na) = 1.702$ $\gamma(Na) = 1.722$ $2V(Na) = 61° 30'$
$\alpha(Tl) = 1.703$ $\beta(Tl) = 1.708$ $\gamma(Tl) = 1.727$ $2V(Tl) = 61\ 24$

The following table gives the analyses of some augites which have approximately the same composition as the Bail Hill mineral:—

	I.	II.	III.	IV.	V.	VI.
SiO_2 ...	45·66	45·52	47·76	45·83	44·18	49·72
TiO_2 ...	2·16	2·05	1·24	3·57	—	—
Al_2O_3 ...	3·53	5·48	4·21	7·47	8·00	4·23
Fe_2O_3 ...	8·78	7·42	7·28	4·90	11·00	4·74
FeO ...	4·16	2·96	2·65	4·11	3·50	5·13
MnO ...	0·19	—	—	—	—	0·50
MgO ...	9·34	12·09	12·12	10·92	10·57	23·19
CaO ...	22·17	22·48	22·18	22·83	23·22	12·49
Na_2O ...	1·50	0·91	1·60	—	—	—
K_2O ...	0·26	0·35	0·36	—	—	—
H_2O ...	1·98	0·37	0·13	—	—	—
P_2O_5 ...	trace	0·71	0·71	—	—	—
	99·73	99·63	100·22	99·63	100·47	100·00

I. Bail Hill.
II. Liebhards, Rhön Mtns.
III. Gehülfensberg, Rhön Mtns. } Analysed by Galkin.[1]
IV. Brown-violet augite from a tephrite; Kaiserstuhl, Baden.[2]
V. Augite from tuff: Boreslau, Mittelgebirge, Bohemia. Analysed by Schmidt.[3]
VI. Augite from Renfrew. Described by Wülfing.[4]

Analyses II and III represent crystals from a basalt-tuff, which bears some petrological resemblance to the Arenig tuffs of Bail Hill.

[1] X. Galkin, Neues Jahrb. Min., 1910, Beil.-Bd. xxix, pp. 681–718.
[2] Quoted in H. Rosenbusch, 'Elemente der Gesteinslehre,' 1910, 3rd edit., p. 445.
[3] W. B. Schmidt, Min. Petr. Mitt., 1882, vol. iv, p. 14.
[4] E. A. Wülfing, loc. cit.

The first three analyses show several striking similarities, particularly in the silica and titanium oxide content, the amount of sesquioxides and the lime-magnesia ratio. They differ from analysis IV, which represents a typical titanaugite from a strongly alkaline rock (tephrite), in two significant ways; namely, they contain less titanium oxide, and ferric oxide preponderates over alumina. In practically all the analyses of titanaugites from basic rocks of pronounced alkaline affinities, such as teschenites, theralites, tephrites, &c., the amount of titanium oxide is over 3 per cent., and alumina preponderates over ferric oxide. The Bail Hill rocks are also alkalic, as the dominant felspars are albite and soda-orthoclase, but they are not so strongly alkalic as the analcite, nepheline, and leucite rocks mentioned above. This lesser degree of alkalinity seems to be reflected in the composition of the augites, which are practically intermediate between the non-titaniferous varieties of the calcic rocks and the so-called titanaugite of the alkalic rocks.

In conclusion, I wish to express my indebtedness to Mr. B. K. N. Wyllie for the loan of many crystals, and especially to Professor H. L. Bowman for his stimulating interest and advice throughout the course of this work.

Since the above work was done, it has been found possible to determine the refractive indices in the *b*- and *m*-sectors. The values obtained were :—

	α.	β.	γ.	
b-sector	1·712	1·717	1·735	Na-light.
	1·715	1·720	1·738	Tl-light.
m-sector	1·710	1·715	1·734	Na-light.
	1·712	1·717	1·736	Tl-light.

Mineralogical Department,
University Museum,
Oxford.

On the occurrence of Bornite nodules in shale from Mashonaland.

By F. P. Mennell, F.G.S., M.I.M.M.

[Read March 17, 1914.]

ABOUT the middle of 1911, I was commissioned to report on a copper mine known as the Umkondo, situated in the south-east of Mashonaland, the eastern province of the territory of Southern Rhodesia. The mine is in a very out-of-the-way spot, about 120 miles from Odzi station, the nearest point on the railway, and to reach it took five days of somewhat rough travelling by cart.

Although this mine was known to be in a sedimentary area and not amongst the Archaean and granitic rocks, which cover much the greater part of Rhodesia, there was no precise information available as to the geological relations of the ore deposit or the characters of the enclosing rocks. I had, however, formed the opinion[1], based chiefly on a few specimens I had seen, that the rocks were of the same age as the Waterberg series of the Transvaal. This view was amply confirmed during the journey to the mine. Apart from two short breaks where the underlying and older granite was exposed in the valleys of the Sabi and Devuli rivers, the beds for a distance of about sixty miles before reaching the Umkondo comprised a series of sandstones or quartzites above, with a shale series below, and, curiously enough, a basal limestone. The last is not apparently known in the Transvaal, but the lithological characters of the other beds are so closely similar, even in detail, to what is described of the Transvaal Waterberg series as to leave little doubt of the correctness of the correlation. An outlier of the coal series unconformably resting upon the older beds was also passed on the way. It may be noted that by some authorities the Waterberg sandstones are

[1] Science in South Africa, 1905; Quart. Journ. Geol. Soc., 1910, vol. lxvi, p. 368.

correlated with the Table Mountain sandstone of the Cape. If so, the beds are Silurian, or possibly in part Lower Devonian. This view is not, however, accepted by the Cape geologists, and they may be older still. They preserve, however, a quite unaltered appearance and have not been affected by any marked folding, crushing, or shearing.

At the Umkondo mine there are good exposures of the quartzites along the edges of the ancient workings, which are extremely large, as well as on the ridge to the south-west of the mine. They dip at a small angle (about 15°) to the north-east and have a rough jointing along the bedding which breaks them into slabs six inches to a foot in thickness. On the kopjes there is often a curious cellular weathering, the surface of the rock being covered with small hemispherical depressions. These evidently originate from the decay of large calcite grains, of which the glittering cleavage planes can be seen among the cementing material on fresh surfaces of the rock. False bedding is indicated in one or two places. Beautiful examples of ripple-marking can also be seen on some of the bedding planes. Though nowhere seen on the surface, it appears that in the flats at the foot of the quartzite ridge, as shown by the mine workings, there are shales which overlie the quartzites. These shales have at their base a remarkable bed which forms the ore body of the mine. It is finely laminated and some of the layers are of a reddish colour which gives it a distinctive aspect. Through it are scattered nodules of copper-bearing minerals, which vary in size from a pea up to several inches across. In the oxidized zone these consist of carbonates, which may also be seen in cracks in the sandstone, chessylite being especially prominent. Below water-level the carbonates are replaced by bornite, from the alteration of which they originated and which occurs to the exclusion of any other sulphide.

The ore body thus possesses unique characteristics and the origin of the nodules presents an interesting problem. It does not seem at all probable that they can be regarded as primary, and yet they have quite the appearance of concretions of pyrites such as are often found in clays or shales, for instance in the London clay of the Kent coast. It is perhaps most reasonable to look upon them as being replacements of original nodules of pyrites; and their external characters distinctly support this presumption. When separated from their matrix some of them show the projecting edges of good-sized cubical crystals. Bornite itself crystallizes in the regular system and is of cubic habit, but it is very rarely found in crystals, and then only in cavities where it has had every opportunity of crystallizing freely; moreover, the individuals are generally small and

occur in extremely confused aggregates from which their edges and corners project in all directions. The view, therefore, that the large cubes seen in the present instance are to be regarded as pseudomorphs after pyrites seems to have much in its favour.

Before concluding, it is worth noting that the shales associated with the ore-bed sometimes show well-marked pseudomorphs after cubical crystals of salt. Some of these are very sharply defined and have the usual hollow faces; others again are small and indistinct. The largest crystal I noticed had an edge of over half an inch long, but a more usual size is between one-eighth and one quarter of an inch. These pseudomorphs are of interest in view of the numerous native workings for salt in the Sabi valley, which are no doubt to be accounted for by the residuum left in these beds after the abstraction of the much larger amount represented by the pseudomorphs. These, it may be mentioned, are the first to be discovered, as far as I am aware, in any South African rocks. Their occurrence possesses a further interest from the fact that we have among the European Trias, where also salt and salt pseudomorphs are found, deposits of copper ore which occur distributed through particular beds of the Lower Keuper just as the bornite does in the much older shales of south-eastern Mashonaland.

Note on the pleochroism of Adamite.[1]

By L. J. Spencer, M.A., F.G.S.

Assistant in the Mineral Department of the British Museum.

[Read November 17, 1903.]

THE mineral adamite ($Zn_3(AsO_4)_2 . Zn(OH)_2$), discovered by C. Friedel in 1866 on specimens from Chañarcillo, Chile, has since been found at only two other localities, namely Cape Garonne in France and Laurion in Greece.[2] At the original locality it would appear to be of rare occurrence, since in the literature mention is made of only two specimens.

It was therefore of interest to find in the British Museum collection a good specimen of adamite from Chañarcillo. This was found amongst the hornsilvers, and the associated adamite had been thought to be fluorite, which indeed, at first glance, with its violet colour and good cleavage, it closely resembles in appearance. The crystals are remarkable by reason of their very strong pleochroism, and as this feature of adamite has previously received no mention it has been thought worthy of placing on record.

This specimen (B.M. No. 44459) was purchased for the museum in 1871, and, under iodembolite, has already been mentioned in this Magazine (1902, vol. xiii, p. 177). It consists of a matrix of ferruginous limestone with some large cleavage surfaces of calcite. A cavity is lined with small colourless crystals of quartz; colourless, amethystine, and brown crystals of adamite; two or three large, greenish-yellow cubo-octahedra of iodembolite; and a little native silver is also present.

The adamite crystals are brilliant and transparent; they average about 1 mm. across, the largest being 4 mm. Although the cleavage angle (*dd'*) is not far from that of fluorite (72° 40′ instead of 70° 32′) it was at once

[1] Communicated by permission of the Trustees of the British Museum.

[2] Since the above was written, adamite has been found also at Monte Valerio in Tuscany (P. Aloisi, 1907), the island of Thasos, Turkey (V. Rosický, 1909), Ain-Achour in Algeria (— Dussert, 1910), and Reichenbach in Baden (V. Dürrfeld, 1912). Pleochroism in the French crystals has been noted by A. Lacroix (Minéralogie de la France, 1910, vol. iv, p. 425).—L. J. S. May 1914.

seen that the symmetry of the crystals was not that of fluorite. Goniometric measurement of two crystals gave angles agreeing with the determinations of Des Cloizeaux. The forms[1] present on a brown crystal were, in order of prominence: $d\{101\}$, $m\{110\}$, $t\{120\}$, $b\{010\}$, $h\{210\}$; and on a violet crystal, *d t m b*.

The colour of the crystals is irregular in distribution; a few crystals are quite colourless, while others are colourless with bands and zones of colour. In the brown crystal mentioned above, the colour is collected near the surface in the prism-zone; and in the violet crystal there are bands and streaks of colour parallel to t (120). The pleochroism is strong enough to be observed by the unaided eye; the brown crystal appears purplish when viewed through the face b (010), and yellowish-brown in the other two directions at right angles. The axial colours for vibrations parallel to the crystallographic axes a, b, and c are:—

Axis.	Brown crystal.	Violet crystal.
a [100]	Rose-red	Rich magenta.
b [010]	Yellow	Rose-red with yellowish tinge.
c [001]	Yellowish-brown	Deep purple.

[1] Letters and indices as in Dana's 'System of Mineralogy,' 6th edit., 1892.

NOTES.

The following deaths have to be recorded:—

Friedrich Julius Peter van Calker (1841–1913) was since 1877 Professor of Crystallography, Mineralogy, and Geology in the University of Groningen, Holland. He was born at Bonn, where his father was Professor of Philosophy, and from here he took his degree of doctor with a dissertation on the optical phenomena in twinned crystals of calcite. Of his few mineralogical papers mention may be made of one on the curious 'barley-corn' pseudomorphs, to which he gave the name pseudogaylussite and described new occurrences from Holland. In 1905 he commenced to issue a periodical publication entitled 'Mitteilungen aus dem Mineralogisch-Geologischen Institut der Reichs-Universität zu Groningen.' He died at Groningen on July 16, 1913.

Theodosij Nikolajevič Černyšev (Tschernyschew) (1856–1914) joined the Russian Geological Survey at its commencement in 1882 and became Director in 1903. He was also Director of the Geological Museum of Peter the Great at the Academy of Sciences of St. Petersburg, and for a time he acted as Director of the Mining Institute. For twenty-two years he was secretary of the Russian Mineralogical Society. Some of his earlier papers were descriptive of the minerals and ore deposits of the Ural Mountains, and in 1883 he gave an account of the Pavlovka (Saratov) meteoric stone. A variety of amphibole has been named tschernichewite after him. A biographical notice, with portrait and bibliography, has been given by A. P. Karpinskij in Bull. Acad. Sci. St. Pétersbourg, 1914, pp. 167–184.

Georg Paul Max Dittrich (1864–1913) was born at Görlitz in Silesia. At Heidelberg he was a pupil of Bunsen and assistant to Victor Meyer, and afterwards Extraordinary Professor of Chemistry. For a time (1891–3) he was chemist on the Geological Survey of Baden. He published papers on the methods of rock analysis, and many of his detailed analyses of rocks appeared in the petrographical papers of other authors.

Adolf Hofmann (1853–1913) was born at Žebrák in Bohemia, and from 1880 to 1888 was assistant in the Mining Academy at Leoben in Styria, where his work was mainly palaeontological. From 1888 to 1909 he was Professor of Ore-deposits, Mineralogy, and Geology in the Mining Academy at Przíbram in Bohemia. In his work on ore-deposits he described various new occurrences of minerals from Bohemia. On his retirement he settled in Prague and his later papers were written in conjunction with Professor F. Slavík. (See F. Slavík, Verh. k. k. geol. Reichsanstalt, Wien, 1913, pp. 339–342; and Centralblatt Min., 1913, pp. 721–722.)

Albert Fairchild Holden (1866–1913) was born at Cleveland, Ohio, and died there May 18, 1913, in his forty-seventh year. He graduated from Harvard in 1888, and, while a good student, was known among the undergraduates of his time as a great football-player, conspicuous for his energy and fairness, qualities prominent in his later career. He was soon associated with his father in silver mines, and became a successful mining engineer and administrator, carrying a load of responsibility in the management of large properties from Mexico to Alaska.

He began to collect minerals in 1895 and continued with ever-increasing activity until his last illness, or for eighteen years. In a history of his collection, prepared not long before his death, many interesting details are given. He called himself essentially a collector, but he had acquired a wide practical knowledge about minerals and the highest critical standards as to what was fairly good and what was superfine, and to obtain the latter he spared neither trouble nor money. It had long been his intention to add his minerals to the Harvard collection, and his purpose was carried out by his trustees soon after his death. In the instructions accompanying the gift he displayed the broadest sympathy with that perplexity, often the lot of curators, who receive large collections duplicating in part their older ones, and a paragraph is worth quoting: 'In regard to the mineralogical collection. There shall be no obligation on the Museum authorities to keep any of the specimens when they have lost their scientific interest. There will be many duplications as the result of taking over my collection. All duplicates, if from my collection, may be sold, exchanged, used for scientific purposes, or given away. I only ask that specimens shall not be removed from the collection until others as good or better have been provided. It is my desire not to handicap the development of the Mineralogical

Department. I wish to aid in bringing the Harvard Mineralogical collection to the highest possible standard.'

The collection contains about six thousand specimens, of which four hundred are large-size exhibition type and the remainder smaller, mostly crystals or groups. It is very complete as regards species and varieties, and in general has a very high standard of excellence, with many unique specimens or sets. The most sensational, from the point of view of both the mineralogist and collector, are perhaps such examples as the two transparent and perfect crystals of kunzite, one a foot long and 5 inches wide, the other shorter and thicker, each weighing 47 oz.; and the large groups and selected crystals of California and Madagascar tourmalines. Mr. Holden bought outright several smaller collections of which the Losee from Franklin Furnace contained many fine local minerals, especially tourmalines and corundums. The forty crystallized zincites from there include a number of perfect pyramids, both large and small. Another rarity are the three transparent crystals of cerussite, twinned on the *r*-law, from Organ, New Mexico, of which the largest is 7 inches long, $3\frac{1}{2}$ wide, and $\frac{1}{2}$ thick. These are extreme cases, but the whole abounds in beautiful material which should yield much to study. Following Mr. Holden's wishes, which again express his good sense, that part which is best suited for the purpose will be incorporated in the public exhibition collections, while with the remainder and much other material a research and reference collection will be formed, to be kept in a separate room where it can be studied and inspected.[1]

Ernst Adolf Hugo Laspeyres (1836–1913) was successor to von Lasaulx as Professor of Mineralogy at Bonn, remaining there from 1886 to 1907, when he was followed by R. Brauns. Previously he had been Professor at Kiel and Aachen, and from 1864 to 1870 he was an inspector of mines attached to the Prussian Geological Survey. He published a long series of notes under the titles 'Mineralogische Bemerkungen' and 'Mittheilungen aus dem mineralogischen Museum der Universität Bonn'; the latter in conjunction with his assistants K. Busz, W. Bruhns, and E. Kaiser.

Hugh Marshall (1868–1913) was a native of Edinburgh, where he graduated (D.Sc. in 1889) and was lecturer in chemistry together with

[1] The above note on Mr. A. F. Holden and his collection has been specially written for this Magazine by Professor John E. Wolff, Curator of the Mineralogical Museum of Harvard University, Cambridge, Massachusetts.

mineralogy and crystallography. He had also studied in Munich and Ghent. In 1904 he was elected a Fellow of the Royal Society, and in 1908 was appointed Professor of Chemistry at Dundee. His translation of Groth's 'Introduction to Chemical Crystallography' appeared in 1906.

John Milne (1850–1913), the pioneer seismologist, was educated at King's College and the Royal School of Mines in London, and after practising as a mining engineer, he was appointed, at the early age of twenty-five, Professor of Geology and Mining in the University of Tokyo, where he remained for twenty years. He was elected an ordinary member of our society in 1878, retiring in 1902. Two papers by him, 'List of Japanese minerals' and 'Experiments on the elasticity of crystals', appeared in this Magazine (vol. iii, 1879). He also published 'Notes on Crystallography and Crystallo-physics' (1879), 'Catalogue of the Minerals, Rocks, etc., in the Imperial College of Engineering' (Tokyo, 1880), 'The Miner's Handbook' (1893). His collection of Japanese rocks, and also the rocks which he collected in Newfoundland, were purchased in 1887 for the British Museum. (For a detailed biographical notice with bibliography and portraits see the series 'Eminent living geologists' in Geol. Mag., 1912, pp. 337–346.)

Friedrich Wilhelm Muthmann (1861–1913) was born at Elberfeld and studied at Leipzig, Berlin, Heidelberg, and Munich, taking his degree at the last of these Universities in 1886. For a time he was instructor in chemistry in the Clark University at Worcester, Massachusetts. Returning to Munich he acted as assistant in Groth's mineralogical laboratory, and afterwards (1895) was appointed professor of inorganic chemistry in the Technical High School. Most of his original work was chemical, relating chiefly to the rare earths, but he was also the author of a number of mineralogical and crystallographical papers. He worked out, simultaneously with Tutton in 1894, the conception of 'topic axial ratios', and this now well-known term is due to him. He prepared and described crystallographically several allotropic modifications of sulphur and selenium, and also did much work on tellurium. Amongst minerals, he described messelite as a new species, and muthmannite (a telluride of gold and silver) was named after him.

Friedrich Carl Alwin Pockels (1865–1913), Professor of Theoretical Physics at Heidelberg, had studied mineralogy and crystallography at Göttingen under F. Klein, T. Liebisch, and W. Voigt, and he was the

author of a 'Lehrbuch der Kristalloptik' (1906). Some of his papers had bearings on crystallographical and geophysical problems. (See J. Koenigsberger, Centralblatt Min., 1914, pp. 19–21.)

Karl Harry Ferdinand Rosenbusch (1836–1914) was born at Einbeck in Hanover, where his father was the master of an orphan asylum. By the irony of fate he was left fatherless at the age of seven, and he owed his early education to the hard work of his mother. Being brilliant at languages he entered the University of Göttingen as a student of philology, but lack of means prevented him from completing this course. He then, for about five years, acted as a private tutor in a family in Bahia, Brazil. Returning to Germany he studied science at Freiburg (Baden) and Heidelberg, and presented his inaugural dissertation 'Der Nephelinit vom Katzenbuckel' (Freiburg, 1869) at the somewhat late age of thirty-three. The study of microscopical petrography being then in its infancy, it became necessary to correlate all the available information relating to the optical properties of minerals as exhibited in sections. This was done by Rosenbusch in his 'Mikroskopische Physiographie der petrographisch wichtigen Mineralien' (Stuttgart, 1873), in the same year that Zirkel published his 'Die mikroskopische Beschaffenheit der Mineralien und Gesteine'. Rosenbusch's second volume, 'Mikroskopische Physiographie der massigen Gesteine', appeared in 1877, and this well-known standard work has passed through four editions (the last in four parts, 1904–1908), whilst Professor Idding's translation, 'Microscopical Physiography of the Rock-making Minerals', also passed through four editions in English.

In 1873, after the publication of his book, he was appointed Professor (Extraordinary) of Petrography at Strassburg, at a time whilst Groth was there as Professor of Mineralogy; and in 1878 he became Ordinary Professor of Mineralogy and Geology in the University of Heidelberg, from which position he retired in 1908. Here by his teaching he attracted pupils from many countries, some of whom collaborated in the publication of the 'Festschrift Harry Rosenbusch' to celebrate his seventieth birthday in 1906. From 1888 to 1907 he also acted as Director of the Geological Survey of Baden. He was elected an honorary member of our society in 1879. The rare mineral rosenbuschite was named after him by W. C. Brögger in 1887. (See A. Harker, Quart. Journ. Geol. Soc., 1914, vol. lxx, pp. lix–lxi; E. A. Wülfing, Centralblatt Min., 1914, pp. 289–299, and Sitzungsber. Heidelberger Akad. Wiss., 1914, Abh. 8, pp. 1–23, with 2 pls.)

Knud Johannes Vogelius Steenstrup (1842–1913) was an honorary member of this society as long ago as 1877. During the years 1866–1889 he was assistant in the University Mineralogical Museum at Copenhagen, and afterwards geologist on the Danish survey. He was a leading authority on the geology of Greenland, to which country he took part in no less than nine expeditions. His first trip, in 1871, was to the island of Disko for the purpose of studying the occurrence of the large blocks of native iron, which had been discovered the preceding year by Nordenskiöld. He proved that this iron occurs embedded in basalt and that it is of terrestrial origin. Two of his papers on this subject appeared as translations in this Magazine (vol. i, 1877, and vol. vi, 1884). A biographical notice with portrait and list of his published papers has been given by O. B. Bøggild in Meddelelser fra Dansk geologisk Forening, 1913, vol. iv, pp. 203–214. See also Geol. För. Förh. Stockholm, 1913, vol. xxxv, pp. 333–338, with portrait.

Hermann Traube (1860–1913) was born at Ratibor in Silesia and graduated at Greifswald in 1884. He was a Privat-Dozent (Titular Professor) of Mineralogy in the University of Berlin, and in 1905 was appointed Extraordinary Professor of Mineralogy at Greifswald, but on account of ill-health he was very soon obliged to retire, and latterly he had lived in Berlin. Between 1884 and 1901 he published more than fifty papers dealing with artificial minerals, microchemical reactions, the occurrence of minerals and rocks in Silesia (e.g. nephrite *in situ*), the crystalline form and optical activity of many organic compounds, and in 1888 appeared his book 'Die Minerale Schlesiens'. He described laubanite as a new species of zeolite.

Grégoire Nikolajevič Wyrouboff (1843–1913) was born at Moscow of noble family, and being of independent means he turned his attention first to medicine and afterwards to philosophy, conducting the 'Revue de Philosophie positive'. He long ago settled in Paris, taking part in the defence of 1870, and since 1904 occupying the position of Professor of the General History of Sciences in the Collège de France. He was an original member of the French Mineralogical Society and twice its president, besides being numbered amongst the very few honorary members. His earliest scientific paper, in 1866, related to the colouring material of fluor-spar, and his thesis for the degree of Doctor of Science at Paris was on the crystalline structure of optically active substances. He made detailed crystallographic determinations of a large

number of artificial compounds, both organic and inorganic, and discussed theoretically their relations as bearing on isomorphism, polymorphism, pseudo-symmetry, and other crystallographic problems. In 1889 he published a 'Manuel de Cristallographie'. Appreciations of his work have been given by H. Copaux and F. Wallerant in Bull. Soc. franç. Min., 1914, vol. xxxvii, pp. 1–4, 44–58 (with portrait).

By the generosity of Mr. F. N. A. Fleischmann, the British Museum mineral collection has recently (1914) been enriched by a large and valuable series of zeolites. During the past fifteen years Mr. Fleischmann, a member of this Society, has specialized in this group of minerals, and he has spared no pains in obtaining the most representative and finest specimens from every locality possible. He has always intended that his collection should eventually become the property of the Museum; but owing to want of space he has decided to transfer at the present time all the specimens from foreign localities. Two large instalments so far transferred include over a thousand specimens, and represent eighty different localities in France, Germany, Italy, Bohemia, Tyrol, Iceland, Nova Scotia, Michigan, California, and New Jersey. Specially remarkable are the very large series of fine specimens from West Paterson and Great Notch in New Jersey.

Each specimen is accompanied by a printed label and a corresponding printed catalogue slip, on which is given very precise information as to the exact locality and mode of occurrence. The name and situation of each quarry or mine are stated, references to the literature are quoted, and unpublished notes of considerable value embody the information collected by Mr. Fleischmann during personal visits to certain of the localities and by correspondence with local collectors and others. Apart from the fact that the collection consists of choice and selected specimens, this precise information adds considerably to its value. Being placed on view in a public museum, the specimens can be admired by the ordinary visitor on account of their beauty of form and delicacy of colouring, whilst to the mineralogist the series will be useful and reliable for purposes of reference.

Amongst other recent additions to the British Museum mineral collection may be noted:—

A fine crystal of transparent lilac-coloured spodumene from Pala, San Diego Co., California. This isolated crystal measures $27{\cdot}5 \times 7 \times 2$ cm. (i.e. nearly 11 inches long and 3 inches wide) and weighs 770·5 grams

(= 27·18 oz. avoirdupois). It was acquired partly by purchase from the Pala Chief Mining Company, and partly as a presentation from Mr. Frank A. Salmons, president of the company, after whom the mineral salmonsite has recently been named. Although not so fine as the crystals bequeathed by Mr. A. F. Holden to Harvard University (see p. 118 above), still it is a remarkable crystal. From the same source was also acquired a specimen of rare occurrence showing crystals of the gem spodumene embedded in its matrix of pegmatite.

The crystal of mauve-coloured apatite from Untersulzbachthal, Salzburg, described and figured by Mr. S. Henson in this Magazine (1883, vol. v, p. 198), which had recently come again into the market at the auction sale, held in London on February 25, 1914, of the mineral collection of Mr. Kendall Hazeldine.

A series of large and delicately crystallized groups of crocoite from Dundas, Tasmania, which with special care had been transported by Mr. A. R. Pontifex. These specimens, together with some others previously in the Museum collection, have been arranged in a special light-proof case on the wall in the Mineral Gallery.

The metric carat of 200 milligrams as an international unit of weight for precious stones is now an accomplished fact, the last two countries of importance having fallen into line in its adoption. In the United States it was adopted from July 1, 1913, and in the British Isles an Order in Council dated October 14, 1913, legalized its use on and after April 1, 1914. Its use for current trade purposes will clearly be accompanied by advantages, especially in international exchanges; but for writers on precious stones, when quoting the weights of historic gems, some caution will have to be exercised. Any ambiguity would be avoided by quoting, whenever possible, the weights in grams, which are easily reduced to metric carats by multiplying by five.

Prof. P. von Groth has now been joined by Dr. Erich Kaiser, Professor of Mineralogy in the University of Giessen, in the editorship of the 'Zeitschrift für Krystallographie und Mineralogie'. The latter editor has compiled a 'Hauptregister' to the first fifty volumes of this periodical, covering the period 1877 to 1912. This differs from the previously-published four volumes of the 'Repertorium' and 'General-register' to each set of ten volumes, in that it indexes only the volumes themselves and takes no account of the literature not noticed in the

Zeitschrift. The catalogue of authors issued last year (1913, 323 pp.) gives the titles of all original papers and translations, and (in German) of all abstracts that have appeared in the Zeitschrift. The first part of the subject-index ('Sachregister') has also been issued (1914, 384 pp., covering A–Hessonite); and a third portion giving an index of localities ('Ortsregister') is in preparation.

The first part of a new periodical 'Zeitschrift für Vulkanologie' (Volcanological Review) has been issued (January, 1914) under the editorship of Immanuel Friedlaender, Director of the new Volcanological Institute at Naples, and published by D. Reimer of Berlin. It contains papers written in German, French, Italian, and English, and is illustrated by numerous plates, on one of which are represented crystals of augite, labradorite, and leucite.

A new edition has appeared (1913) of Sir A. H. Church's well-known 'Precious Stones', issued as a Victoria and Albert Museum Handbook. Several additions have been made and the volume increased by twenty-nine pages. The descriptions of the specimens in the Townshend collection are now incorporated in the body of the work under each species. An appendix gives a list of faceted gem-stones which have recently been presented to the Museum by Sir A. H. Church for the purpose of making this collection more representative.

REVIEWS.

Minéralogie de la France et ses colonies. By A. Lacroix. Vol. V, pp. 501. (Paris: Ch. Béranger, 1913. Price 35 francs.)

Volume IV, published in 1910 and noticed in this Magazine (vol. xvi, p. 71), was to have been the last of this important and valuable work, the author having then abandoned his original intention of giving a detailed geographical index. Fortunately, however, with the assistance of Colonel Azéma the laborious task of indexing and correlating all the localities mentioned in the set of volumes has now been effected, adding greatly to the value of the work for purposes of reference. The present volume contains a second supplement (94 pages) of descriptive matter, dealing mainly with new occurrences of minerals from Madagascar. The elaborate geographical index extends to 464 pages. By including certain localities in countries bordering on France (Alsace-Lorraine, Belgium, Spain, Italy, Switzerland, Channel Islands) the usefulness of the index is increased. Finally, there is a systematic table of all the mineral species described, and a general index and list of errata to the five volumes.

The Curious Lore of Precious Stones. By George Frederick Kunz. Pp. xiv+406, with 49 plates (6 coloured) and 24 text-figures. (Philadelphia and London: J. B. Lippincott Company, 1913. Price \$5.00 = 21*s.* net.)

The scope of this new book of Dr. Kunz's is indicated in the sub-title: 'being a description of their sentiments and folk lore, superstitions, symbolism, mysticism, use in medicine, protection, prevention, religion, and divination. Crystal gazing, birth-stones, lucky stones and talismans, astral, zodiacal, and planetary.' We hasten to explain, however, that although precious stones are endowed with certain important characters, fortunately for mineralogists these do not include sentiments, superstitions, &c. The superstitious regards for precious stones date back to remote periods and have little foundation in fact, but it is curious to find how much seriousness is attached to 'birth-stones' even to the present day.

The volume is based on the notes which Dr. Kunz has collected from a wide range of sources and during a long period of years, and he has

contrived to make the whole readable and of interest. The illustrations are good and varied in character: they are, however, unnumbered, and some of them do not appear to be referred to in the text.

Manual of Petrographic Methods. By ALBERT JOHANNSEN. Pp. xxviii + 649, with 770 figures. (New York and London: McGraw-Hill Book Company, 1914. Price \$6.00 = 25*s.* net.)

Dr. Johannsen, Assistant Professor of Petrology in the University of Chicago, has produced a book on petrographic methods which is well in advance of anything previously attempted in the English language. Besides outlining principles, he has aimed at giving a brief yet clear account of all the pieces of apparatus and all the methods hitherto published, the descriptions being supplemented by full references to the literature. The book will therefore be indispensable to the advanced student and worker in petrography, whilst the treatment is sufficiently lucid for it to be also of use to the elementary student provided he receives some guidance in his selection. The subject-matter is treated in forty-two chapters, and there is also an appendix giving useful formulae, tables, and recipes. The following selected chapter-headings will give an indication of the scope of the work: Mineralogical principles, Stereographic projection, Principles of optics, Lenses, The Microscope (construction, various models, use, and care of), Observations in ordinary light, between crossed nicols, and in convergent light, Measurement of the optic axial angle, Determination of specific gravity, Mechanical separation of rock constituents, Microchemical reactions, Preparation of thin sections, Petrographic collections (field work and office work). The book is well printed and the numerous text-figures are excellent.